100 BOOKS SCHEME

THINGS AROUND US SERIES

COAL

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THINGS AROUND US SERIES.

HUNDRED BOOKS SCHEME.

During my student days and several subsequent journeys in Europe, I tried to find out what it was which gave the people of Europe an advantage over us. I was anxious to ascertain this more particularly because I was, from my observation, firmly convinced that the Indian mind was quick and subtle and, type for type, the Indian was more capable than the European. I discovered that there were two factors which gave special advantage to the people of Europe. One was the availability of books on technical *subjects—elementary, middling and advanced—at very low* prices, and the other was the existence of evening and night classes in technology in most of the cities of Europe, which people engaged during the day could attend in order to advance their knowledge in one or other subject, in which they were interested. Whereas in India a man, who was recommended for the job of a liftman, would be still found there after ten years, in Europe such a man would pick up elementary books on mechanics and electricity, read them during his leisure time, attend evening classes, add to his knowledge and then get on to a job requiring superior knowledge. From this point onwards again, he would, by the same process, try to add both to his knowledge and status as well as self-respect and earnings.

In India there are no books on technical subjects in most of the vernacular languages, with which alone people are familiar. There may be isolated productions of very elementary character, or of very advanced character, on some subjects in some of the languages. But we took a full range of topics and enquired and we found that there was no systematic series of deliberately prepared books giving useful information and a chance to a man to system-

atise his general knowledge. It is to make up this deficit in the requisite equipment in India that this scheme has been prepared In eight vernaculars in India, illustrated books on technical subjects, compiled with great care and bringing up-to-date information on the topics dealt with, would be brought out. They would be prepared on a uniform basis and there would be cross references and index volumes attached to the series.

The knowledge is not new. It is extant in the English language, in which there are many books available at 6d., 9d., 1s. 0d., 2s. 6d. and 5s. 0d. and more. These books are available only to readers in the English language, but they are written abroad and without specific reference to Indian conditions, whereas our intention is to have these books prepared carefully and wherever possible these books prepared carefully and wherever possible to bring in as many known facts relating to the subject from the Indian point of view, so as to make the book more useful to the Indian reader.

This is a task, which should have been performed by Government either in the Centre or in each respective Province. It is a task, which could have been handled satisfactorily by the various Universities in India. But it is an omission, which has very far-reaching consequences in the life of the people, and it was considered desirable by the Trustees of the Lotus Trust that this work should be attempted independently and carried through so far at least as the preliminary compilation of the books and the preparation of the necessary picture blocks was concerned. This work is indeed costly and for this purpose the Lotus Trust has set aside a sum of Rs. 25,000; a contribution of Rs. 18,000 was received from the Trustees of Sir Dorab Tata Trust, which is gratefully acknowledged. The translation in various provincial languages in India and the publication of these books in thousands of copies at a very cheap price, if possible, of about 4 annas, or a figure well within the reach of the poorest, is a task, which will still require finance and co-operation of a wide range, both official and non-official. Encouragement in the form of a money grant to the scheme has already been received from the Govern-

ment of India. Considerable progress has been made in the work of compilation.

Since this work was begun in the middle of 1944, some fifty out of a hundred and ten subjects have been already dealt with and others are in the process of compilation. The list of the subjects is elastic and some topics may be dropped out and others added to.

This series does not aim merely at benefiting boys in the teen age, who are attracted towards a subject. The series is also intended to benefit workmen and staff, who are engaged in industry and who desire to know more about the activity, from which they are deriving their livelihood. It is also intended to benefit University students and, above all, to benefit the general reader who wants to add to his knowledge on one or more topics. Many men know loosely many things about many subjects, but the knowledge is not systematic and it is derived frequently from hearsay. Many men would like to know fully about subjects, which attract their notice. The series would also be an invaluable addition to school libraries and, it is hoped, would help in raising the standard of general knowledge of vernacular teachers.

The growth of industry in India has been considerable in the manufacture of some articles and altogether negligible with regard to others; the spread of knowledge covering the whole field of "THINGS AROUND US" will doubtless stimulate interest in those things, which have hitherto failed to receive attention from entrepreneurs.

Another set of people, who, we expect, would benefit from this series when it is available in every Indian language, would be workmen, who have been rendered literate by the efforts of the State. Adult literacy is in the forefront of the national programme and it is our intention to make available something in which the grown-up man can find interest. The active worker, when he just begins to read, should have the chance to peruse in print the topic, in which most of the things are known to him by actual work.

Another object of this series is to remove the libel on the Indian workmen and the Indian humanity generally, that there are few inventions in India. This is entirely due to the accident that improved machines are brought from abroad and even when the Indian handles them and repairs them, he has not a vivid mental picture of the whole process or the whole purpose. Once the Indian workman has full knowledge of the industry in which he is engaged, I am confident that the Indian mind is capable of inventions, which will astound the world. India must stop importing in the mass equipment from abroad except sample models, and the illiteracy of the workman and the peasant must be liquidated. The effective spread of knowledge through the books compiled in this Series in all Indian languages would then bear fruit; the farmer will cease to be conservative and the workman will have the courage and good sense to make suggestions involving greater convenience for himself and leading to improvement of the process and of the machines.

Kodak House,
Hornby Road, Bombay.
1st March, 1948.

MANU SUBEDAR,
Chairman,
The Lotus Trust.

100 BOOKS SCHEME.

Topics on which compilation is completed

1. Rubber
2. Coconuts
3. Lighting Materials
4. Cotton
5. Wool
6. Rivers
7. Mountains
8. Sea
9. Ships
10. Light
11. Astronomy
12. Geology
13. Soils
14. Flowers
15. Fruits
16. Foodgrains
17. Seeds and Kernels
18. Vegetable Oils
19. Mineral Oils
20. Coal
21. Tobacco
22. Coffee
23. Fibres
24. Motor Car
25. Paper
26. Non-Ferrous Metals
27. Insects
28. Precious Stones
29. Plastics
30. Matches
31. Bee-keeping
32. Stone
33. Silk and Art Silk
34. Noble Metals
35. Gums and Resins
36. Roads
37. Power
38. Watches and Clocks
39. Microscope
40. Air Conditioning
41. Meteorology
42. Telegraph and Telephone
43. Photography
44. Dyestuffs
45. Glass
46. Sugar

Topics on which compilation is progressing

1. Tea
2 Salt
3. Soaps
4. Inks
5. Cement
6. Manures
7. Colloids
8. Condiments
9. Architecture
10. Aeroplane
11. Radio
12. Nutrition
13. Sanitation
14. Care of children
15. Anthropology
16. Fisheries
17. Geography
18. Irrigation
19. Machine tools
20. Workshop
21. Minerals
22. Archaeology
23. Block Making
24. Printing Press
25. Boilers
26. Mechanics
27. Cinematography
28. Disinfectants
29. Electricity
30. Explosives
31. Internal Combustion Engines
32. Perfumes
33. Musical Instruments
34. Paints and Varnishes

Topics on which compilation is not yet taken in hand

1. Iron and Steel
2. Timber
3. Leather
4. Furniture

5. Type Foundry
6. Forests
7. Agriculture
8. Animal Husbandry
9. Food Preservation
10. Public Health
11. Market Gardening
12. Knitting and Sewing
13. Cookery
14. Nursing
15. Laundry
16. Cleanliness
17. Typewriters & Comptometers
18. Pencils & Crayons
19. Cotton Textiles
20. Pottery and Ceramics
21. Abrasives
22. Ice & Aerated Waters
23. Book Binding
24. Chemistry
25. Botany
26. Zoology
27. Biology
28. Physics
29. Physiology
30. Railroad
31. Public Works
32. Armaments
33. Pictures & Picture Frames
34. Carpets
35. Fountain Pens
36. Carpentry
37. Fire-fighting Equipment
38. Drawing Materials
39. Buttons

(Contributions or co-operation from scholars and others interested in these topics would be welcome.)

COAL

CHAPTER I

INTRODUCTORY

Definition

The word 'coal' will be found defined in a dictionary as a solid black combustible substance dug out of the earth and used for fuel. This definition would be accurate upto a point but it would exclude peat which is decayed vegetable matter occurring in boggy places and which, being not solid, has to be dried before being used as fuel. Furthermore, some coal occurs in surface out-crops and need not be dug out but can be picked up for fuel. Scientifically, coal is defined as "a compact stratified mass of mummified plants (which have in part suffered arrested decay to varying degrees of completeness) free from all save a very low percentage of other matter." The word coal has been in use for a long time (being spelt 'Cole' or 'Coalle' upto the middle of the 17th century) and is derived, probably, like its Indian equivalent **Kolsa**, from an Arabic or similar root **(Kala)** signifying black. The substance however should not be confused with charcoal which we use as fuel in our kitchens and which is artificial coal made by charring wood under smothered combustion; to avoid this confusion, coal proper was at one time known as pit-coal or sea-coal.

Historical

It is admitted that coal was known as a fuel to the early Roman settlers in Britain, as coal cinders have been found in conjunction with Roman tools and implements among the remains of the buildings known to be Roman; but coal had apparently gone out of use in England for sometime due probably to prejudice; and indeed many Europeans, not even knowing

that coal could burn, were surprised at the strange story of Marco Polo that "the Chinese were making good fire from black rocks'. As however the area under forests began to dwindle reducing thereby the supply of wood charcoal, coal again began to attract attention. In the beginning of the thirteenth century the first charters were given to the freemen of Newcastle and the monks of Newcastle to dig pits for coals. But this coal, when sent to London, was immediately rejected as prejudicial to the health of its citizens on account of the smoke and gases emanating therefrom; and, in fact, proclamations were issued both by King Edward I and Queen Elizabeth forbidding its use during the sitting of Parliament. It was the latter's successor King James I who, being accustomed to burning coal at his seat in Fife, introduced it to the Palace at Westminster and, thus giving it royal recognition, made it a commodity of national importance. What gave it world-wide significance however was the use of coke for smelting iron about 1750, the introduction of Watt's Steam-engine in 1769 which speeded up railway transport and steam navigation, and the introduction of gas-lighting in 1807. It was an Engineer by name Murdock who had first utilised the gas generated from coal for illuminating his house in 1792 and made a public display of it at Birmingham 10 years later. Since these events, coal has received such national importance that it is sometimes known as 'black diamonds'.

Black Diamonds

The phrase 'black diamonds' is certainly not inappropriate: for, diamond happens to be the purest form of carbon found in nature, and coal in its various forms is known to be composed, mostly if not entirely, of carbon. In fact the transition from coal to diamond is found in graphite (also known as black lead or plumbago) which has a grey metallic lustre and which is purer carbon than the hardest coal, containing not more than 5 per cent of ash and other impurities. The successful manufacture of artificial diamonds by a French Chemist, Moissan, by crystallising the carbon of sugar through heating in a crucible in an electric

furnace up to 3000° C in conjunction with molten iron and subjecting it later to tremendous pressure on cooling, as well as the frequent deposition of an imperfect graphite in some of the hottest retorts where gas is distilled from coal, supply sufficient evidence of a carbonaceous link between diamonds, graphite and coal.

Peat

Although there has been costly and protracted litigation in England over the exact nature of the substance coal, there is a general consensus that it is of vegetable origin and contains sufficient carbon to allow of its continuous combustion in the fire-place of an ordinary grate. Coal may be regarded as the outcome of a transformation by which the oxygen and hydrogen of woody and vegetable *tissues are eliminated in proportionally larger quantity* than carbon, thus increasing the percentage of the latter. The various kinds of coal met with in the bowels of the earth show "stages begotten by different degrees of disentanglement of the contained gases." These volatile constituents occur in a greater degree in **peat** which is vegetable matter in the incipient stages of decay. The formation of such accumulations of decaying vegetation can only be possible where the physical and climatic conditions of the country allow of an abundant rainfall as well as depressions in the configuration suitable for retaining moisture. Peat-mosses, rushes, horsetails, reeds and other flora peculiar to bogs are thus able to grow and thrive upon the ruins of their ancestors; and the gradual decomposition of vegetable matter while saturated with water leads to the formation of peat which is rare in the tropics but develops largely in temperate and cold or arctic regions, Ireland being, par excellence, the land of bogs and peat.

Lignite

Though peat cannot be regarded as coal proper, it represents the first stage in (and affords a clue to) the formation of coal. The second stage may be regarded as **lignite** or **brown coal** which occurs abundantly in Germany and

New Zealand. Here, a considerable quantity of volatile matter has been parted with and the percentage of carbon which is about 50 pr cent in wood has increased to about 67 per cent in lignite. Though known as brown coal, it is sometimes almost black: it has, as its name denotes, a woody grain: it is often soft and moist when fresh, soils the fingers on touching, and cracks to pieces or crumbles to powder when dry. It gives out less heat, produces an abundance of smoke and emits choking sulphurous fumes in burning. It has a lower specific gravity than black coal. It is comparatively of a recent geological age and has a high volatile hydrocarbon content which has led to its carbonisation for recovery of light oils, wax and paraffin. Its high moisture content is reduced in steam-heated driers to about 15 per cent for compression through presses into brown briquettes of a high calorific value, 7 inches long 2¼ inches wide and 2 inches deep, with rounded edges, for domestic as well as industrial purposes.

Bituminous Coal

The next kind of coal is **bituminous coal** also known as soft coal though it is really not soft. It is black in colour but has a rather more waxy appearance than hard coal. Bituminous coal appears to have been squeezed and heated in the earth to a greater extent than lignite and has therefore divested itself of much of its hydrogen. Its carbon content is over 80 per cent and in one variety, the 'Caking Coal', so-called because it tends to cake together through exudation when burning, it is sometimes as high as 88 per cent. Caking coal breaks readily into small irregular cubes and has a shining resinous lustre. It burns with a bright flame and a little smoke and is therefore used for domestic purposes though it requires frequent stirring. It is used also for making coke and for generating gas. Another variety of bituminous coal is known as 'cherry Coal' which resembles caking coal but does not fuse in burning and yields a coke in powder form or in the form of the original coal. Caking and cherry coals often occur together in the same bed and are often known as soft coals compared to

the 'slate' or 'splint' coal which is hard. The last-named has a more distinctly laminated appearance, breaks with an uneven or splintery fracture and is usually obtained in larger pieces. It is difficult to kindle and does not alter its form in burning. Splint and cherry coals are often known as 'free burning coals' due to the fact that they allow space for air to pass freely through the fire. The word 'bituminous' applied to these Coals is misleading, as there is no ready-formed bitumen in them; and, since it is their distillation that yields bituminous products, they should be rather called bituminiferous.

Cannel Coal

The next harder coal is **Cannel coal** which is also known as 'parrot coal' in Scotland. The word 'cannel' is probably derived from 'candle' as this coal burns like a candle: 'parrot' signifies its cracking or chattering noise when thrown into the fire. It is usually earthy-looking, though some varieties are bright and shining and rather brown than black. It is a compact coal and breaks with a slaty or conchoidal fracture. It does not soil the fingers and can be made into ornaments, inkstands, vases and even polished tables. The story goes that the Duke of Bridgewater once served his guests with dinner in plates made of cannel coal, and, after the dinner was over, relegated these plates to the fire to the great amusement of the guests. The highest form of ornamental cannel is 'jet' which is not used as fuel but for making buttons, beads, etc. But the real cannel which has a carbon content of about 84 per cent is the most valuable of all coals, as it is wholly employed for making gas or as a source of paraffin oil.

Anthracite

The hardest of all coals is anthracite with a carbon content never less than 80 per cent and often as high as 95 per cent. It is stony looking, rather clean, does not soil fingers and is heavier than other kinds of coal. It is shiny and of a glossy black colour, being sometimes irridiscent. Though difficult to kindle, it burns with pretty flames short and

blue, not very bright, almost smokeless and odourless It was in fact advocated at one stage that in view of these properties its use for household purposes should be enforced by law. In burning, it gives off an intense heat and is therefore consumed principally in smelting metals and in raising steam; it is sometimes therefore known as steam or stone coal. As anthracite is practically pure carbon, it leaves very little ash and is therefore ideally suited for use in enclosed stoves for heating houses or water or for cooking.

Classification

There are a number of kinds of coal which have received special names in commerce; but they can be easily classified among the four groups, anthracite, bituminous, cannel, and lignite, described above. The International Geological Congress of Toronto adopted these four classes in the main in the order named but divided them into one, two or three sub-classes acording to their mean composition and physical properties and gave them letters, thus A1A2, B1B2B3, C and D1D2, acording to their 'fuel ratio' of fixed carbon to volatile matter.

Composition

Though some geologists regard coal as a mineral, this is not correct as coal does not have a definite chemical composition. It is usual therefore to call it a carbonaceous rock of the sedimentary group. All carbonaceous rocks, peat, lignite or coal, have however the same qualitative composition, differing only in the proportion in which the constituents are present. These constituents are carbon, hydrogen, oxygen and nitrogen together with a varying proportion of mineral known as ash. There is also about 8 lbs. of sulphur in every thousand. The different varieties of coal from peat upwards show a progressive alteration, a decrease of oxygen and nitrogen and a corresponding concentration of carbon and hydrogen. This difference is due in part to the nature of the original mother substance or vegetable slime (or sapropil, as it is called), the action of geological forces or of bacteria; and the admixture of extraneous sub-

stances like clay or sand brought in by the decomposing water.

Geological Formation

Coal is found in layers or strata from one inch upto 30 or 40 feet in thickness. Very thick beds may be regarded as the accumulation of several seams, 7 or 8 feet being regarded as the maximum thickness of a single seam. Those which are under 2 feet in thickness cannot be worked profitably. The principal rocks found interstratified with coal are sandstones, shales, limestones, ironstones and fireclay. Geologists have divided the various strata of which the outer crust of the earth is composed into three distinct groups, Primary, Secondary and Tertiary, according to the ages of their depositions and each of these groups is again subdivided into 'systems' and 'series'. Thus, the Primary or Palaeozoic group which is the oldest is composed of a number of systems of which a later one is known as the carboniferous. It is in the upper series of this Carboniferous System, known as the **Coal Measures**, that the majority of rocks in which coal occurs are found, though some Coal Seams are met with in rocks much older in the geological scale. While the Russian Coalfields are comparatively older and the English coalfields all belong to the Coal Measures Series, those of Transvaal and Natal are more recent and belong to the Cretaceous System of the Secondary Era. Though we have in India a small percentage of our coal in beds belonging to the last named System, the bulk of our coal is found in the Gondwana System which corresponds to the Upper Carboniferous and higher series. Lignite, wherever found, is mostly always of the Tertiary age.

Smoke

All coals emit a greater or lesser quantity of smoke while burning. In temperate climates where coal (or firewood) is burnt in the hearth or the fire-place, chimneys are always provided for this smoke to escape into the atmosphere. Now, smoke consists of particles of pure unconsumed carbon which is accompanied in its passage up the chim-

neys by sulphorous acid, sulphuretted hydrogen, hydro-carbons, vapours of various kinds of oils and ammonia. Some carbon is deposited as soot on the walls of the chimneys etc. but the rest goes into the atmosphere, thus giving rise to fogs through each particle of carbon attracting to itself aqueous vapour from the air. The nett result of vast quantities of smoke polluting the atmosphere in large cities is regarded as harmful to public health, and one reason why silver-work tarnishes rapidly is said to be the presence of sulphuretted hydrogen in the air derived through the combustion of coal. It is estimated that the soot falling in London alone in one year can cover the whole of Hyde Park (about 390 acres) one foot deep and that the potential fuel, so escaping in the air of England through incomplete combustion of coal, can be reckoned at about three million tons per year. It is clear that wherever smoke and especially black smoke is produced, fuel is being consumed wastefully.

Uses

Modern Science has made it possible to guard against this waste. For, when coal is heated out of contact with air, it resolves itself into a solid stable residue known as coke and some volatile matter, the principal constituent of which is gas. Both coke and gas are now used as fuels; and, in fact, for iron smelting or in furnaces provided with a strong draught, hard coke produced through long continuous heat is an imperative necessity. Besides their importance as fuel, coal and its by-products have a number of uses in every sphere of life. It has been said that from coal tar alone, many more chemicals can be built up than there are visible stars in the sky! These may range from anaesthetics and tear-gas to dyes and plastics. We shall endeavour to describe the most important ones in the fourth chapter. Suffice here to note that the epithets King Coal and Black Diamonds, are richly deserved by the black rock to the happy possession of which, England is said to owe, in great part, her prosperity and her pre-eminence in commerce and industry.

CHAPTER II

COAL-FORMATION

Coal-measures

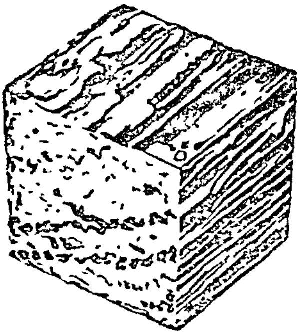
We have already said that coal is found in a series of beds known as the Coal-Measures. It occurs as sheets or seams of varying thicknesses between beds of rock and usually resting upon a thicker or thinner bed of clay, known as the under-clay. These successive alternations of beds of clay, coal and rock may be repeated several times and have been described jointly as the coal-measures. In some localities, the coal measures are more than 14,000 feet thick and enclose eighty or a hundred seems of coal, each with its under-clay and separated from the seams above and below by beds of sandstones and shales. It is necessary to remember these facts in order to appreciate how coal was formed.

Woody Origin

There are two theories with regard to the origin of coal, the growth-in-place theory and the drift theory. The former envisages that coal was formed where it is actually found today, while the latter likens it to other sedimentary rocks, being formed by accumulations through drift. Both theories are however agreed that coal is of vegetable origin, being nothing more than woody matter from which a great part of the gases etc. have been squeezed out by pressure which, acting in conjunction with heat and fermentation, has greatly altered its structure. Microphotographs reveal rounded yellow patches or streaks in horizontal sections and more elongated bars and granules in vertical section of coal not unlike the grains of wood, as will be apparent from the following photograph of a polished cube of coal.

Mineral Charcoal

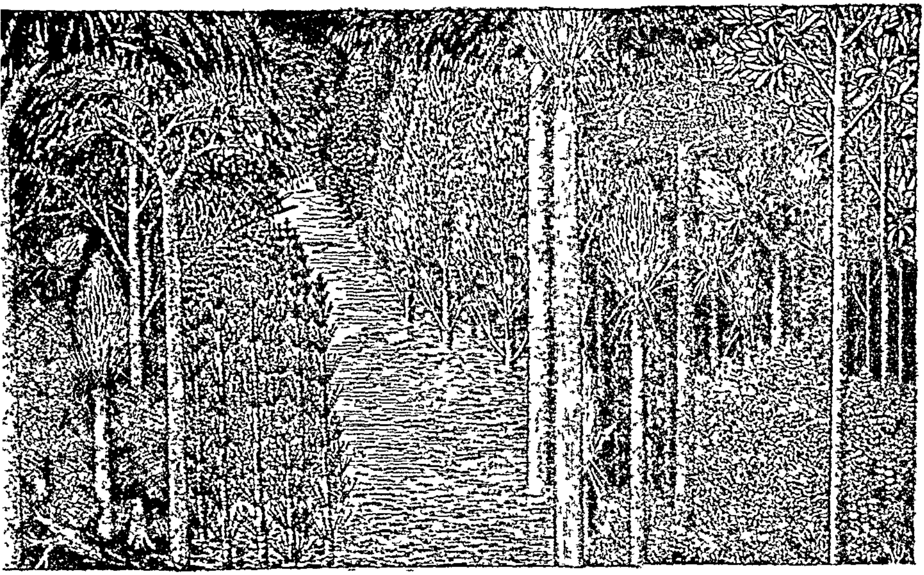
Now, a closer examination reveals that most coal is composed of two constituents: mineral charcoal and coal proper. The former is found to consist mainly of the remains of stems and leaves of plants or of crushed and flattened bark and outer layers of tree-trunks, the inner wood being completely destroyed. Even today when a tree has remained fallen on the ground for sometime, we find that the dense wood has decayed, having suffered from the ravages of insects more intensely than the bark. Such a tree is but a mere shell which crumbles under the weight of our feet and the hollow inside is full of insects, vermins or reptiles which have sought refuge therein. The trees which are found in mineral charcoal present parallel conditions: the barks are mere double shells flattened together in consequence of the destruction of their woody core. In the hollow stools of Nova Scotian Coal-fields, the remains of snails, millipedes and salamander-like creatures have in fact been identified, embedded in a deposit of a different character.



Ancient Forests

In describing a typical forest the remains of which have gone to the formation of coal in remote geological epochs, we can do nothing better than quote Mr. Huxley. "In endeavouring to comprehend the formation of a seam of coal, we must try to picture to ourselves a thick forest, formed for the most part of trees like gigantic club-mosses, mares'-tails and tree-ferns with here and there some that had more resemblance to our existing yews and fir-trees. We must suppose that, as the seasons rolled by, the plants grew

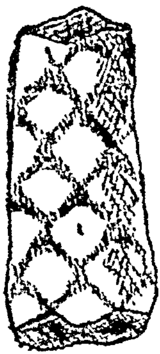
and developed their spores and seeds; that they shed these in enormous quantities which accumulated on the ground beneath; and that every now and then they added a dead frond or leaf; or, at longer intervals, a rotten branch or a dead trunk, to the mass". The following diagram gives a generalised reconstruction of a Carbonaceous forest such as the one described:—

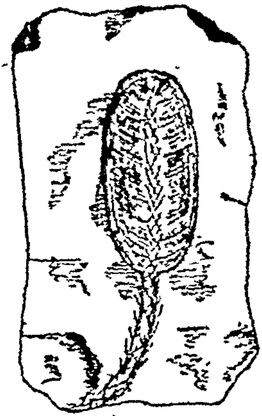


Club Mosses

Such a forest could have been hardly picturesque. The trees have mostly tall, straight trunks with very few branches at the top and with very few leaves on a branch. The enormous club-mosses attaining a height of sixty feet and a girth of over five, compare but poorly with their existing counterparts (**Lycopodiums**) which are small, insignificant, creeping herbs. They were known as **Lepidodendrons** (on the extreme left of the above diagram) and unlike the modern club-mosses their trunks showed scars formed by the attachment of petioles or leaf stalks. They however

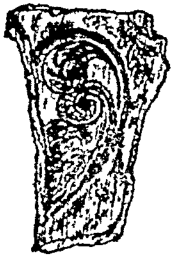
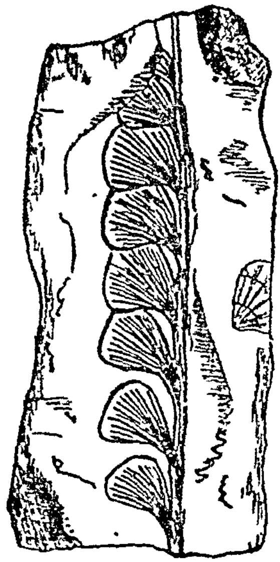
bore similar cones or spore-cases and had equally minute spores or seeds about which we shall speak later. The diagram on the left below is a cast showing the leaf-scars found in carboniferous sandstones and on the right a cone of Lepidodendron found in a coal-shale:—





Tree-ferns

The Plants which have gone to make up coal can only be identified by searching among the shales, clays and sandstones which enclose the coal seams. Here, we find petrified or fossilised specimens which give us an idea of the dense forest vegetation as well as of the type of life that was then inhabiting the earth. Among animals, evolution had not yet proceeded beyond the reptiles and there were no birds, or mammals. Among the plant kingdom, the trees had not yet known to bear flowers and in addition to the most lowly forms like seaweeds and lichens, there were ferns, equisetums and mosses. The ferns were in profuse abundance and had structures similar to their modern counterparts with large fronds curling like a bishop's crozier and with venation comparable to that of many existing species, as depicted in the fossils below:—

The tree ferns were indeed gigantic, a faint idea of their luxuriance being obtained from the modern tree-fern forests of Tasmania and New Zealand.

Horse-tails

Another tree of the coal-forest to which we may specifically refer because of its abundance is the horsetail or **Equisetum** which belongs to the order **calamites.** The modern horsetail which grows in marshes and ditches is a graceful, erect plant with a thin jointed stem and foliage in whorls, but the stem of the fossil vertical-ribbed calamite attained a thickness of five inches and grew to a height of about eight feet; it had a fistular pith and a thick smooth bark which has almost always disappeared leaving a fluted stem: it bore cones. A number of other plants flourished at the period of coal-deposits; their petrifactions have been examined and critically studied by paleobotanists whose works should be consulted for a fuller study. It is enough for our purposes to note that the coal-forests were densly packed with gigantic trees which belonged

to the lower rather than to the higher groups of plants and that the then climatic conditions, a moist, humid and warm atmosphere with abundant rainfall and with possibly a greater percentage of carbonic acid gas which prevented radiation of heat from the earth, led to the formation of vast swampy expanses over almost all the terrestrial surfaces of the globe. There was no well-marked division into botanical provinces under varying climatic conditions as is the case with modern floras and the Arctic plants apparently flourished quite as well as the Southern floras in the same localities.

Resinous Spores

We have said earlier that most coal consists of mineral charcoal and coal proper. We have so far described the former. Let us now focus our attention on the latter. The coal proper, or saccular matter as it is called, constitutes by far the greater part of all bituminous coals: it is unlike mineral charcoal and does not consist of stems or leaves. It is proved to have been formed from the seeds, spores and spore cases of the lowly plants that were thriving in those days. We are familiar with fern-spores which are tiny brown dustlike particles that can be seen on the underside of fern-leaves and serve them as seeds. The living club-mosses too have spores and sporangia which can be compared to those of the extinct Lepidodendrons. These spores and sporangia contain so much resinous matter that they are now largely used in the manufacture of fireworks (as Lycopodium powder) and are so impermeable to moisture that they make an excellent coating for medicinal-pills. A single spike of a tiny club-moss when shaken sheds a cloud of spores: if we imagine this repeated over a thousand times from each branch of a tall Lepidodendron and this multiplied over a million times from the millions of trees of the coal-forests, we can get a picture of the copious showers of spores that would have been falling among the dead debris of vegetable matter. The ravages of insects, bacteria, floods and weather would soon reduce

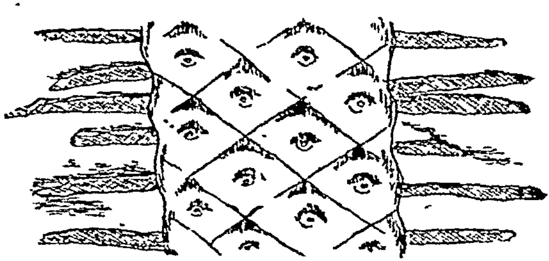
the leaves and stems to their carbon skeletons but the impervious spores would remain as a comparatively unaltered and compact residuum forming a sort of matrix in which the mineral charcoal would become permanently embedded. Coal then may be regarded as the result of accumulations of spores and spore-cases in which other decomposed parts of plants have become encrusted as mineral charcoal.

Geological Factors

This kind of coal formation is certainly true of most bituminous coals as well as of cannel coals. The so-called white coal of Tasmania, Tasmanite, is proved to be almost entirely a compacted mass of spores and spore-cases. But when we come to anthracite, the position is a little more difficult. Here comes in the "peat to anthracite" theory of Arber. This theory assumes that all coals started life with an initial stage of Peat. "The peat later became converted into Brown Coal, next Brown Coal passed into Humic or Bituminous Coal and finally, at least in some cases, Anthracite resulted." We have already referred to the formation of peat through the gradual decomposition of vegetable matter in water-logged bogs. Let us imagine these beds of peat subjected to an ever-increasing pressure of accumulating strata above them: this would certainly compress them into coals of various kinds, depending upon the amount of pressure available; let us also bring in the action of the internal heat of the earth: this would cause them to part to a varying degree with some of their component gases; let us visualise the action of anerobic bacteria which would suck them dry of their remaining oxygen, the depradations of insects, animals, fungi and floods causing decomposition on a major scale and the tremendous earth movements resulting in elevation, depression, tilting, fracturing or faulting of the strata in which the coal deposits occur. All these forces, working singly or simultaneously, must ultimately lead to the production of the amorphous matter which we call coal.

Under-clay

Every seam of coal, whether a few inches or many feet deep, whether occurring singly or as a succession of layers, is found to be resting on a bed of clay—which is known as the under clay. Now, there is conclusive evidence to show that every under clay was once a surface soil on which grew the verdant forests of the coal age. This clay is found to be full of carbonised root fibres and in some cases trunks of trees have been discovered in coal-seams showing radiating roots passing into the under clay. Many such roots known as stigmaria of **Sigillarian** trees which grew to a height of 60 to 70 feet have been discovered as fossils in the under-clay, some with protruberant tubercles. The following diagram shows fossil stigmaria which, at an early stage, were mistaken for aquatic plants. As Prof. Dawson remarks: "A single trunk of Sigillaria in an erect forest presents an epitome of a coal seam. Its roots represent the stigmaria under clay: its bark, the compact coal: its fallen leaves and fruits with remains of herbaceous plants growing in its shade mixed with a little earthy matter, the layers of coarse coal."



Submergence and Emergence

Having visualised a coal-forest, let us see how the decaying vegetable debris, instead of remaining on the surface as peat, came to be buried and compressed as coal. Now, the evidence afforded by the calcareous and shelly remains of fossil animals found in the strata immediately above and below the coal-seams points to the presence of

large rivers, estuaries or shallow seas in the immediate vicinity of the coal forests which would have brought and deposited sediment in the shape of sand and mud. The alternate sinking and uplifting of land in that age has been admitted by every geologist: so that "when the coal-forest area became slowly depressed, the waters must have spread over it and have deposited their burden upon the surface of the bed of coal in the form of layers which are now converted into shale or sandstone." The abatement of water would spread sheets of alluvium or fine mud over the area, thus forming a new soil or under-clay for a fresh forest-growth. The process of ups and downs would be repeated several times, the sea even sometimes encroaching upon the land-forests and helping in the formation of sandstones which are also connected with some strata of the coal measures. In the Lancashire Coal-field, there are said to be about 7,000 feet of carboniferous strata enveloping eighteen seams of coal one above the other—which means that on eighteen occasions separate and distinct forests must have grown on identical spots and that, in the intervals between each of these occasions, geological movements of the earth must have brought these forests beneath riparian or marine waters, giving rise to the sandstones and shales occurring between the different seams of coal. In place of subsidence of the forests, there may have been occasional uplifts, in which case the forests would grow for longer periods before being submerged. The then warm and humid atmosphere would have not merely produced an abnormally abundant vegetation but would have also helped in the decaying and disintegrating processes.

Growth-in-Situ

The above description is indeed convincing of the growth-in-situ theory and gets added confirmation from the peat-beds of Europe and the Great Dismal Swamp of North Carolina and Virginia. The latter is a swamp of peat and forest which at one stage occupied over 2,200 square miles and is today after drainage about 38 miles long and 15 miles abroad. The area is said to be sinking

even as the coal forests are assumed to have gradually subsided in ancient days. But those who hold that coal was not formed in place but that the material which formed the coal-seams was drifted into position, being transported there from a distance, point to the fact that the great mass of rocks forming the coal measures are formed of water-borne or water-deposited material and that coal must have also been formed likewise, especially as coal is usually stratified rock. This drift theory does not explain satisfactorily the prominent features of all coal seams though it does help us to understand a few stray seams like those of France, Natal or India. Some of the French coalfields are found in basins formed in metamorphic rocks and rest directly on them without the intervention of sedimentary rocks, a fact which points strongly to their having been water-borne. We shall explain the Indian formations in the fifth chapter. But the majority of coal-seams are proved to have been formed in places where the coal forests originally grew, helped here and there perhaps by drifted vegetable material from higher lands or by the invasion of virgin soils by swampy or estuarine conditions. Though the areas of coal accumulation were frequently submerged, "true coal appears to be a subaerial accumulation by vegetable growth on soils which were wet and swampy but not totally submerged."

Period of Time

It has been asserted that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least fifty generations of Sigillariae (whose roots we have already described) and therefore an undisturbed condition of forest growth enduring through many centuries. From this, it has been calculated that, assuming that each generation of coal plants took ten years to come to maturity, each foot-thickness of coal would represent 500 years; if the thickness of the seam is fifty feet, it would have taken at least 25,000 years. But there are often more seams than one in a given coal-field and the seams are intercalated

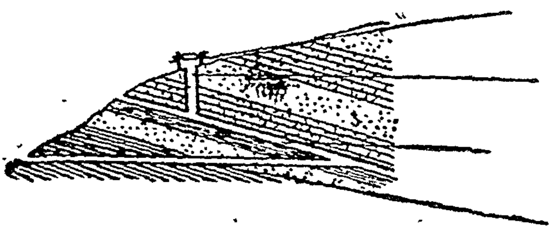
with strata of sandstones, shales and other deposits which are often more than two miles in vertical thickness and which would all require an equal if not a greater measure of geological time for their deposition. The time thus taken would, for a two-mile thickness, be $2 \times 5280 \times 500 = 5.280,000$ years. This computation need not be adhered to rigidly but gives an approximate idea of the enormous period of time during which conditions of growth, submergence, deposition and emergence described in this chapter have to be visualised as having taken place. This is not surprising in view of the evidence furnished today by submerged forests, raised beaches, drowned valleys, the remarkable changes of level in the Bay of Naples and the known rising of land at Stockholm at the rate of six inches per century—which all go to show that in past times due to varying physical conditions a large part of the earth's surface must have been alternately raised into land or depressed below sea-level.

CHAPTER III

COAL-MINING

Early Methods

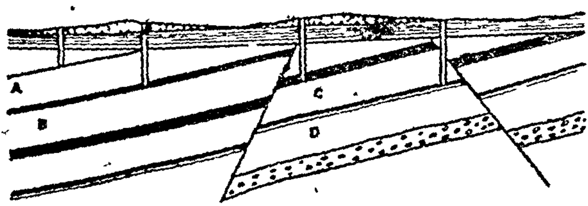
In this chapter we shall endeavour to describe shortly how coal is 'won' from the bowels of the earth in which it lies hidden. The subject, though interesting, is highly technical and we can only touch here on its barest fringe. In early days coal found in out-crops was merely picked up and collected or recovered by open-working or by quarrying. Sometimes "bell-pits" were sunk—which were small holes or shafts driven through a few feet of overlaying strata and then widened out to allow for excavation. "Strip-mining" is practised even now when the coal lies so near the surface that the overlying earth and rocks can be first removed through electric or steam shovels. The "adit system" once very common could only be possible in hilly countries. An adit may be defined as a tunnel cut through other strata so as to reach a seam of coal. The coal was worked by means of narrow passages driven in the seam, small pillars being left for supporting the roof. It was carried up a shaft on the backs of labourers climbing up ladders or hauled up by means of pulleys. The adit also served as a drain for seepage water; but ventilation was always poor, fires being occasionally lit in the shafts



to heat the air and so to increase the current. This system, depicted below, could not naturally work far beyond the coal seam nor in flat country.

Preliminary Survey

Before a modern colliery or coal-mine is opened, it is customary to make a preliminary survey of the nature of the beds lying above and below the reported coal-seams and of the geological structures like faults, folds, overthrusts etc. to which these beds have been subjected in the interior of the earth. This survey is usually made through bore-holes sunk at various centres and more usually near the outcrops. Coal, as we have already seen, occurs in a succession of seams so that such boreholes, (depicted below, where the letters A, B, C. D represent the coal-seams) will not only reveal the character of the various strata but also the relative thicknesses of the coal seams and their dips. A **dip** may be defined as the angle which an inclined stratum makes with the horizontal.



Shaft-sinking

After this survey is made, the first operation is the sinking of a shaft. In Great Britain every coal mine must be provided with two shafts, affording separate means of ingress and egress, not less than 15 yards apart and having between them a communication of not less than 4 feet by 4 feet. These shafts are known as the down-cast and the up-cast shafts respectively. Shafts are usually sunk near the centre of the coal-field so as to enable large areas to be worked all round. These shafts are sometimes vry deep and need not necessarily be directly vertical. Several inclined shafts at Michigan are about 8,600 feet at an angle

of 39° to the horizontal. Such inclined shafts are always rectangular: when vertical, they may be cylindrical too. All shafts are usually lined with masonry, iron-work or timbering. Shaft-sinking in solid rock containing little water is comparatively easy: after preliminary excavations with pick and shovel, drilling and blasting can do the rest. But where sinking has to be done in unstable or watery soils, the process becomes both difficult and expensive. Where much water is encountered, a separate pump compartment becomes necessary: sometimes, the watery soil has to be artificially frozen before excavation through cold brine being pumped through a number of drive-pipes laid down about three feet apart: or the soil is hardened by injecting cement grout through boreholes at pressures of 1000 to 3000 lbs. per sq. inch. The shafts are then sunk through these frozen or hardened strata and lined wth concrete steel etc.

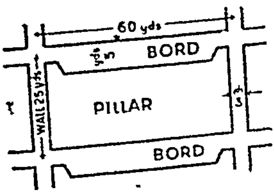
Water-pumping

Where coal can be reached at small depths, a number of shafts may be sunk for different areas: but in most cases it is usual to cover thousands of acres underground by a couple of pits placed about the centre of the coal-field, so that the mine can be worked in every direction radiating from the centre. It is also customary to sink to the lowest point of the field for the convenience of drawing the coal as well as of draining the water. In practically every coal-mine, oozing and sometimes gushing water is a powerful enemy to contend with; for every ton of coal recovered from a mine several tons of water may have to be pumped out to the surface: otherwise, the mine would be drowned out as had happened during the great Coal Strike of 1893 when the pumps had ceased working and certain mines became flooded and consequently unworkable. What are known as wet mines involves a continual fight with water, costing a deal of money.

Bord and Pillar System

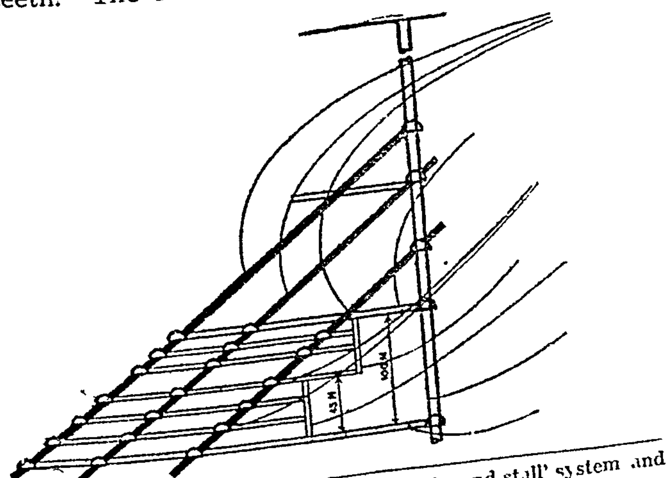
The actual lay-out of a mine after the shafts have touched coal depends on the nature of the coal, the thick-

ness and extent of the seam, its dip, the nature of the surrounding strata, the amount of water etc. Usually, one of two systems (with necessary modifications) is employed, the **Bord and Pillar System*** and the **Long-wall System.** The former which is the more ancient and is still practised largely in America consists of driving roads in the coal seam so as to form pillars which would support the roof as the workings advance and which can be subsequently removed. The narrow roads are known as **walls** and the broad ones at right angles bords. The following diagram shows a plan of the bords, walls and pillars



Long-wall System

In the Long-wall System, the main road is like the backbone of a comb with side tunnels like several widely placed teeth. The intervals between the teeth are filled



* It is also known as 'stoop and room', or 'pillar and stall' system and sometimes 'narrow work'.

with 'gob' or 'goaf'—which may be shale, clay, rock or other valueless rubbish separated from the coal. The coal is attacked on a line running across the ends of the teeth. The roads are cut high enough for labourers to work in, even though the seam may be a few feet thick. The sides are built up by walls of stone so that the pressure on the goaf becomes reduced. Where the seams of coal are however highly inclined, main 'drifts' or 'cruts' (horizontal passages) are tunnelled at right angles to the shaft and these are connected at intervals by 'cross-measure drifts', as shown in the above section of a Westphalian Colliery.

Coal-cutting

Coal is got at from the seam by cutting: this is mostly a manual operation in England where only 20 per cent of the national output is said to be obtained through mechanical coal-cutters. In America, however, all these operations are done by machinery now mostly electric: even the shovels for removing the coal after it is cut are sometimes electric. The actual cutting, when not mechanical, is by means of a pick-axe. The coal is 'holed' by undercutting a groove at the bottom about a foot wide and sloping down to nothing at the far end which may be 3 or 4 feet deep. An overhanging block of coal is thus left which would tumble down in chunks of its own accord or is brought down by driving wedges along the top or by blasting. These operations are very strenuous and risky; the holing has to be done in a constrained position and the blasting can only be done by drilling special holes in the coal-face and firing explosives through time or electric fuses after all the miners have left the danger zone.

Propping

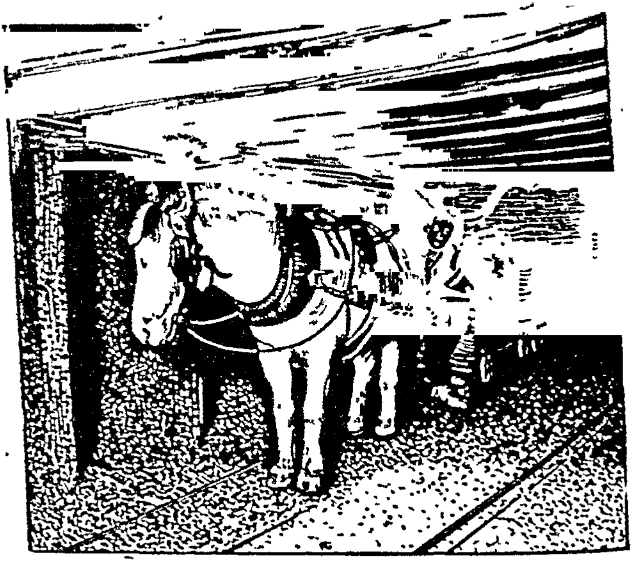
As the coal is removed, the roof of the exacavation is supported by packing waste material as well as by a double row of props usually of pine-wood (or sometimes of steel or tubing) as shown below:—

In fact, the pressure overhead becomes so great that all underground galleries, in coal mines must have adequate support. Near the entrance to the shafts and in main roads, the walls and roof are built in through masonry or with metal rings as in a tunnel: but where the galleries are smaller and of a temporary nature, props are invariably used, England importing over 3 million tons of timber annually for the purpose. As can be imagined the caving in of the roof is likely to prove very dangerous and expensive: this happens even in the Bord and Pillar System when the coal is hard, the floor is soft and the pillars are too small or are irregularly removed: a 'creep' then sets in and the roof gradually collapses. The filling or packing of excavated spaces with waste material or goaf in order to offset the effects of subsidence is now compulsory where workings extend below surface buildings In a few anthracite collieries in America, culm or coal dust and other waste are washed down into exhausted pits by water, thus giving a compact filling after the water has drained away.

Haulage

Coal broken at the working face is removed to the haulage level either by manual labour or through 'tubs' or wagons drawn by little ponies or through mechanical

power on rails laid on wooden cross-sleepers. as shown below:—



On account of the narrow awkward spaces through which they have to pass, the ponies employed in coal mines can only be small. These ponies have their stables underground and are brought to the surface only at rare intervals. Horse traction, though not obsolete, has given place to mechanical tramways worked either through compressed air or by electricity. There are even machines for loading coal into the trucks. In steeply inclined seams, shoots are sometimes used or iron plates are laid on which the coal slides down to the loading place. Where convenient 'Conveyors' made of rubber or woven cotton convey the coal through a continuous or jerking movement. Some haulage is done through endless ropes or chains travelling always in the same direction up one track and down the other, the waggons being connected to them singly at intervals and being unhitched at the end of a trip. Overhead trolley wires so common in American and German mines are prohibited in England owing to the dangers con-

sequent on flashing. In many cases, the tubs or trucks are unloaded at the base of the shaft by means of rotary dumps into the 'skip' which finally raises the coal to the surface where the arrangements for winding rope pulleys and drawing up the cage are of considerable complexity. The winding engines usually located in the 'hoist-house' are worked by steam or sometimes by electricity.

Treatment above-ground

When the cage arrives at the platform forming the working top above the mouth of the shaft, a peculiar arrangement permits the tubs to be pushed out and the empty tubs to be pushed in for the return journey. Each loaded tub is passed over a weigh-bridge for weighment and is run into a 'tippler' which turns it upside down and pours its contents on to slanting screens. These screens have small holes or slots at the upper end followed by two or more stretches of larger sizes of holes. The coal is moved slowly forward by a shaking motion of the screen so that all but the large lumps are screened out through the holes. All lumps except the smallest sizes and dust (known variously as slack, dross or duff) fall on to travelling belts which may be 300 feet long and 3.5 feet wide and are carried past a line of pickers who take out and remove the waste and rubbish as it passes by, leaving the clean coal on the belt. The smaller coal passing through the screen is carried by another belt to a separate sizing-plant consisting of vibrating or rotating screens where it is separated into several sizes (known as trebles, doubles, single nuts, peas and beans etc.) These are washed free of impurities by water. As coal is lighter than the rubbish mixed with it, a stream of water passed through the mass would drive away the coal and leave the heavier stone, slate etc. behind. Anthracite coal which is used in small sizes only is broken up in a crusher before it is screened and washed: hence the surface building of an anthracite coal-mine is known as a 'breaker' and that of other coals a 'tipple'. Modern screening, breaking and washing plants are indeed elaborate and costly. A modern dry-cleaning

plant for nut coal which is liable to discoloration with water passes the coal over an inclined glass-plant which is kept clean of falling dirt by the play of compressed air.

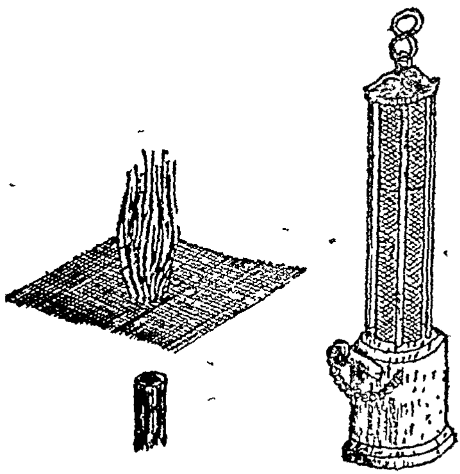
Miners

Coal-mines are generally worked continuously but not by the same batch of miners. There are usually three shifts of about 8 hours each. Every miner on arriving at the pit-head goes to the lamp room where on surrendering his disc or calling out his number he is given an electric lamp to be clamped on his forehead or a locked safety lamp, with which he mounts the platform where the coal tubs are unloaded and joins a queue to enter the cage. There are usually two cages, one ascending and the other descending: the cages are often double-decked and may accommodate forty or fifty men. At a given signal, the cage descends into the shaft at a high speed. Here the miner finds himself in a vaulted chamber and rests for a few moments to get his 'pit-eyes' before proceeding "in-bye" to his assigned working place; when his shift is finished, he locks up his tools by a chain and padlock, puts on the clothes which he had taken off and tramps back to the pit-bottom to be hauled up by the cage. There are washing and bathing facilities provided at most pit-heads for the benefit of the miners. It is estimated that there are some 400 pit-head baths in England which can accommodate about half a million persons. The cost is met largely by grants from the miners' Welfare Fund derived from a compulsory levy of ½d. per ton on all coal produced. About 84 per cent of the labour employed in a coal mine works underground consisting of colliers, men and boys, who actually get the coal (36 per cent), watermen, repairers, traffic men including horse-keepers, foremen etc. The rest 16 per cent, work at the surface in hauling, weighing, screening, stoking etc.

Fire-damp

One of the greatest dangers which await miners is that of explosion from the presence of inflammable gases in the mines. The great walls of coal which bound the passages

in mines are constantly exuding supplies of gas which increase in volume (and are then known as 'blowers') when banks of coal are suddenly brought down by dynamite, explosions etc. This coal-gas known also as fire damp is really methane or light carburetted hydrogen which has been accumulating in the coal for millions of years and gets a chance of coming out when the coal is hewn. It is only dangerous when it is mixed with air, for then the amount of oxygen becomes extremely low. When anything between 6 to 13 per cent of fire damp is mixed with air, the mixture becomes explosive. A flame once started travels quickly through it, the heat causing air to expand and thereby exploding the roof, walls etc. When in ancient days the fact that danger arose from a mixture of methane and air was not realised, naked lights and especially tallow candles were very much used below ground and were the cause of many serious accidents. These accidents have now become rare due to the invention of the Safety lamp by Sir Humphrey Davy in 1815. The principle of this lamp is simple. If a piece of wire gauze be held over a gas jet before it is lit, the gas can be ignited above the gauze but the flame will not pass downwards towards the source of the gas, as depicted below.



Safety Lamps

In the safety lamp, the little oil lamp is surrounded by a circular funnel of gauze which prevents the flame from passing through it to any explosives gas that may be floating about out-side. There have been marked improvements in the manufacture of such lamps but the principle is still the same. These lamps are issued in a locked condition to the miners but even then certain accidents have been traced to careless miners surreptitiously opening their lamps for smoking purposes. Though electric lamps are now generally issued to miners, safety lamps are necessary for testing the presence of gas which can be detected in amounts less than one per cent by turning down the wick till there is a small blue flame when the gas can be seen burning above it. It has been held that the danger of explosions is greater when there is a surcharge of coal-dust: this is overcome by a system of fine sprays of water through pin-holes pricked in a series of pipes.

Ventilation

Another reason why explosions are rarer now than formerly is because the mines are properly ventilated so that the gas is never allowed to reach an explosive concentration. Apart from the fact that the twin shafts tend automatically to produce a current of air downwards through the down-cast and upwards through the upcast, this current is quite insufficient even for inhalation by the army of workers breathing inside the mine and must be supplemented by artificial means. Among these means may be mentioned pumps, fans, pneumatic screws and even furnaces located in specially constructed chambers at the bottom of the upcast. The current so intensified is further manipulated through barriers, trap-doors etc. in such a way that it traverses through every portion of the mine, before being shot out through the upcast.

Accidents

While there has been steady progress in the prevention of fatal accidents in mines, coal-mining is unfortu-

nately a dangerous occupation. For the purpose of official returns, these accidents have been classified under six heads: (1) explosions of fire-damp and coal dust, (2) falls of ground, (3) shaft accidents, (4) underground haulage accidents, (5) miscellaneous underground and (6) those occurring on the surface. Of these, falls of ground account for about 50 to 55 per cent of the total accidents and haulage accidents due to the moving tubs and ropes underground about 20 to 25 per cent. Some of these are indeed avoidable and chapters have been written, diverse methods suggested and special bye-laws enforced for ensuring the safety of colliery workers. In spite of their dangerous occupation and liability to accidents and respiratory diseases, statistics show that miners live longer and enjoy better health than most men. In point of lowness of death rate from accidents, Belgium stands first, with India as a very good second, among all the great coal producing countries of the world, while the United States where machinery is used to a much larger extent and the industry works at a very high speed occupies the worst position.

CHAPTER IV

DERIVATIVES OF COAL

Primary Uses

We have seen that coal is primarily used as a fuel: and the greatest users of coal in this fashion are the steam engines and the electric power stations. Where hydro-electric generation is not possible, the most important electrical installations all over the world are powered entirely by coal. Even in Germany which produces mostly lignite or brown coal, over forty per cent of the electric power generated and consumed was produced through coal. But, apart from fuel, the immediate products of coal are gas, coke, and tar with some ammoniacal liquor. The following are the products per ton from caking and cannel coal respectively.

	Caking coal	Cannel Coal
Gas, Cub.feet	9,500	10,100
Coke, lbs.	1,540	1,390
Tar, lbs.	90	120
Ammonical liquor, lbs.	80	64

Coal Gas

When coal is heated out of contact with air, it resolves itself into a solid stable residue known as coke and some volatile matter the principal constituent of which is coal-gas. The coke residue may be gasified in steam to make water gas which is often mixed with coal gas for public supply and distribution in pipes. Gas under certain circumstances can be more economically employed as a source of heat than an ordinary coal fire. In towns, it is always at hand and can be applied by the use of burners constructed for heating or cooking purposes at a moment's notice. This readiness of application is also taken advan-

tage of in the gas engine as well as in the use of gas as an illuminant either in the naked flame or through gas mantles. Coal gas cannot be said to be the gas of any one substance in particular, being a mechanical mixture of at least three different gases viz. marsh gas or fire damp which is one of the lightest hydrocarbons (CH_4), hydrogen and carbon monoxide. These gases constitute about 87 per cent of the whole volume of coal-gas. Another six per cent is made up of olefiant gas or ethylene (C_2H_4) and other olefines which give gas its illuminating power. Gas also contains small quantities of nitrogen, carbonic acid gas, sulphuretted hydrogen and carbon bisulphide vapour which are often removed as noxious impurities before gas is distributed.

How Manufactured

Coal-gas is manufactured in a series of usually five retorts which are huge cast iron vessels encased in strong brickwork and in which the coal is placed to be heated by a large furnace underneath. Each retort has an exit pipe, through which the gases generated are emptied into a 'hydraulic main', a long horizontal cylinder, in which the gas begins to deposit some of its impurities. The immediate products of distillation, after steam and air, are gas, tar, ammoniacal liquor, sulphur in various forms and coke, the last being left in the retort. Tar and ammoniacal liquor are deposited in the hydraulic main and gas proceeds to the 'condenser' consisting of a number of U-shaped pipes. Further impurities are collected here on the tar pit and the gas, helped on by the exhauster, passes on to the 'washers' or 'scrubbers', a series of tall towers from which water is allowed to fall as a fine spray which helps in the removal of large quantities of ammonia, sulphuretted hydrogen, carbonic acid and oxide, and cyanogen compounds. The gas then enters the 'purifier' where it is robbed of its carbonic acid and many sulphur compounds through admixture with lime or hydrated oxide of iron. The gas then passes on into the 'water chamber' over which the 'gas-holder' or 'gasometer' is reared into which

it rises through the water. This short description of how gas is made is only intended to show the principle and need not be taken too rigidly.

Coke

We have seen that Coke is left as a residue in the retorts Coke is also manufactured specially for certain purposes, e g for iron smelting. The special ovens in which it is made may be classified into three principal types, direct-heated ovens, flue-heated ovens and condensing ovens. They are variously known as retort ovens, beehive ovens, or by-product ovens. However manufactured, coke is a partially graphitised carbon and consists essentialy of carbon together with some incombustible matter or ash which was contained in the coal from which it is derived. It also contains small quantities of hydrogen, oxygen. nitrogen and a little water. When produced rapidly and at a comparatively low heat as in gas-making, coke is of a dull black colour with a loose spongy texture and can be ignited with comparative ease, even in open fire places; but when a long continuous heat is used, it is hard and dense, semi-metallic in lustre and silvery grey and can be burnt only in furnaces provided with a strong draught. It is the latter coke that is indispensable for iron and steel smelting, the substance being sufficiently dense to resist oxidation by carbon dioxide in the higher regions of the furnace. About 18 million tons of coal are used annually in England for the manufacture of gas and about an equal quantity for the manufacture of coke, the total quantity of coke so produced by either process being about 23 million tons. America too produces a like quantity.

Coal-Tar

Now, the distillation of coal for the production of gas or coke yields a viscous oil fraction known as coal-tar at 900° to 1200°C. The yield and composition of tar varies according to the nature of coal carbonised, the type of retort used and the manner and degree of heating. Coal-tar is a thick black oily liquid with specific gravity higher

than that of water and is obtained along with ammoniacal liquor when the volatile products of the carbonisation of coal are cooled. On settling, the ammoniacal liquor comes to the top and can be drawn off. A small quantity still left in the tar is got rid of through dehydration by gentle heating. One tone of coal yields about 10 gallons of tar that is, about 5 per cent by weight. Coal tar in the crude state is used as an anti-corrosive paint or as a preservative in tarring ropes etc. at sea*; but for use on road surfaces or as a binder, it is 'prepared' by distillation till the heavier oils begin to distil. Prepared tars are also used in the manufacture of steel linings and of roofing felt. Coal tar is composed of a number of entities which can be separated by distillation and which yield a "veritable chemists' treasure house of by-products".

Benzol Products

Tar by-products are obtained by straight distillation and the fractions usually collected are crude naphtha (first runnings) 2 per cent, light oil 7 to 8 per cent, crude carbolic oil or light creosote 8 to 12 per cent, heavy creosote 10 to 12 per cent, anthracene oil 6 to 15 per cent and pitch 50 to 60 per cent. Now these fractions distil off from tar in progressive sequence varying with the temperature, the last to distil being anthracene oil which requires a boiling point of about 300° C. These fractions can be used by themselves but yield a number of commercially useful derivatives. Thus, the first two fractions are hydro-carbon oils and constitute the 'crude benzol' which is used extensively in the paint and varnish trade and for dry cleaning. When used as a motor fuel it is purified by redistillation and careful fractionation so as to eliminate carbon disulphide which also distils with the first runnings along with thiophene. The latter is removed by treatment with concentrated sulphuric acid. Pure benzene so obtained is very volatile and inflammable: it is also used for removing grease stains: it yields in company with nitric acid nitrobenzene which has an odour of bitter almonds and is used

* Hence the word 'tar' meaning a sailor.

in perfumery or which through certain processes can be reduced to aniline for manufacturing the famous aniline dyes which have now supplanted the dyes of vegetable origin. The other products of commercial importance obtained in the early stages of tar distillation are toluene. phenol and pyridine. Toluene and phenol are the starting points of two well-known explosives, T.N.T. and picric acid and are also useful in the manufacture of tear gas. Pyridine is used medicinally (for asthma and for its iodine derivatives), as a denaturant for alcohol and as a solvent for salts, oils, rubber, etc.

Light Creosote Products

The third fraction, crude carbolic oil or light creosote. distils over at about 200°C. Its major constituents are naphthalene (about 40 per cent), the lower phenols, carbolic acid and cresol. Naphthalene is used in the manufacture of synthetic porcelain for the electric industry, and phenols and cresols in the manufacture of synthetic resins. After carbolic acid is extracted from light creosote, the remaining sharp oil is cresylic acid which is the basis of many common disinfectants. Saponified by emulsifying agents, it is found in commerce under the trade names of Lysol, Creolin etc. Light creosote is also used by itself as a timber preservative.

Heavy Creosote Products

The fourth fraction is heavy creosote or creosote oil containing carbolic acid, cresol, naphthalene, anthracene and other hydro-carbons. It makes an excellent fuel for diesel engines or for oil burning furnaces. It is also useful as absorbent in the recovery of light hydrocarbons from coal-gas. Its best application however is in the preservation of wood like railway sleepers, paving blocks. telegraph posts, etc. as by closing pores it renders the material a non-absorbent of water. Heavy creosote is also converted into a disinfectant powder by admixture with slaked lime and has been suggested as a soil fertiliser.

Anthracene

The fifth fraction, anthracene oil, contains anthracene, phenathrene and carbazole. It is green in colour and after removal of crystalline anthracene can be used like creosote as a fuel for Diesel engines or as a gas absorbent. It is also used as a lubricant for clay moulds in brick-making and as a component of grease for lubricating wire-ropes. Naphthalene is used for manufacturing impregnated fire-lighters and though it can be used in place of petrol as a motor fuel, it is claimed that its solution with petrol functions as an anti-detonating agent. Sulphurated products of phenathrene and carbazole have been applied as tanning agents.

Pitch

Pitch, which is the residue left in the still in the distillation of tar, is used as one of the components in protective paints and varnishes or for making artificial asphalt. Mixed with coal it is used as a fuel but its greatest value is as a binder for small coal in the preparation of briquettes, the coal slack being mixed with molten pitch (about 10 per cent) and compressed into uniform blocks. Pitch when further carbonised yields a coke suitable for the manufacture of electrodes. It is also used as a filling material for resins in the manufacture of cold-moulded articles or for water proofing and rubber processing.

Pharmaceutics

The pharmaceutical importance of coal-tar products is indeed great. As antiseptics, antipyretics, hypnotics, anaesthetics, etc. the derivatives of benzene, toluene and phenol are widely applied. It has been said that the growth of synthetic organic chemistry from the products has enabled the medical profession to fight a winning battle against bacteria and trypanosomes. The manufacture of perfumes and soaps, pastes and polishes, varnishes and lacquers, dyes and solvents require, like the photographic industry, large quantities of the pure constituents of coal tar.

Ammonia

We have said earlier that a certain amount of ammoniacal liquor also distils with tar when coal is carbonised and that this liquor floats by reason of its lightness on the tar. It consists of a solution of the various salts of ammonia but chiefly the carbonate and sulphide and is therefore the principal source of ammonia. As it can be easily volatilised by heat, its vapour is passed through sulphuric acid to be converted into sulphate of ammonia; or, by saturating it with hydrochloric acid, sal-ammoniac or chloride of ammonium is formed; and from either of these compounds, carbonate of ammonia or smelling salts can be made. Ammonia and its compounds are valuable substances in dyeing, for manure, in pharmacy and for many other purposes.

Lignite Products

We have so far referred to the products obtained from coal as incidental to the manufacture of gas and coke: the coal used here is mostly bituminous. But the less mature kind of coal which we have described as lignite or brown coal is also used, in the countries in which it is produced and especially in Germany, for straight distillation. It then yields light oils, paraffin and montan wax. The first two products are obtained by low temperature carbonisa-tion in special retorts, the gases distilled from the coal being drawn off and condensed in the ordinary way. Light oil thus obtained forms between 16 to 20 per cent in pro-portion to tar and is used as a substitute motor fuel. Para-ffin is required in the manufacture of candles or for coating cream and milk cartons, cake-boxes, etc. Montan wax is obtained by treating dried lignite with a mixture of hot benzol and alcohol which are later evaporated and used over again. This wax is used for making gramophone records, lacquers, boot polishes, special greases, etc.

Hydrogenation

A process allied to carbonisation described in the last paragraph is the liquefaction or hydrogenation of coal.

Coal is here subjected to the influence of hydrogen under heat and pressure (3,000 lbs. to the square inch) so that its hydrocarbons as well as some of its fixed carbon become saturated to produce a tarry liquid akin to crude petroleum which, on distillation, can yield a motor spirit, lubricating oil, fuel oil and pitch. The vast quantities of natural mineral oil still available from the earth have not yet made it necessary to have recourse to such artificial petroleum.

Alcohol

We have seen that one of the constituents of coal gas is ethylene C_2H_4: this is an unsaturated hydrocarbon which means that all its carbon valences, not being saturated with hydrogen, are free to attach themselves to other radicles. It is thus possible to convert ethylene into ethyl alcohol for use as a liquid fuel. It has been estimated that in the emergent conditions of a war such conversion from the Gas Works of the United Kingdom would make available for that country some 27 million gallons of a good substitutable motor spirit. Coke oven gas is first purified by the complete elimination from the crude gas of tar, naphthalene, ammonia, and benzol in direct recovery plants and of sulphuretted hydrogen, water vapour and higher olefinic hydrocarbons by special processes. The resulting gas is then scrubbed with 95 per cent sulphuric acid (which is also a coke oven product) at a temperature of between 60° and 80° C. on the counter current principle in special absorption towers, the time of contact between gas and acid being only 2½ minutes. The absorption of ethylene by sulphuric acid forms ethyl hydrogen sulphate which (either through oxidation by electrolysis yields acetic acid or) through hydrolysis by dilution of the acid with water yields ethyl alcohol and sulphuric acid.* The latter can be used over again in the process. The quantity of ethylene and

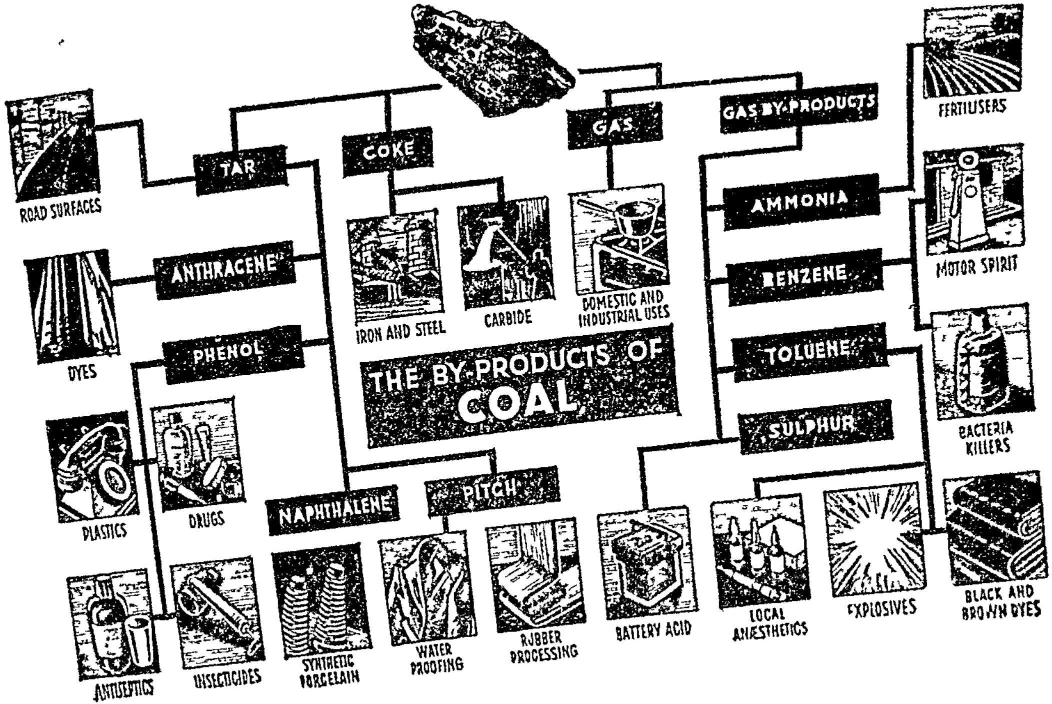
* This proces can be described chemically thus :—

	Ethylene	+	Sulphuric acid	=	Ethyl Hydrogen Sulphate
	C_2H_4	+	H_2SO_4	=	$C_2H_5\ HSO_4$
and	Ethyl Hydrogen Sulphate	+	Water	=	Alcohol Sulphuric acid.
	$C_2H_5\ HSO_4$	+	H_2O	=	C_2H_5OH and H_2SO_4

its homologues in coke oven gas is said to be about 2 per cent by volume which would, on conversion, yield 1.6 gallons of absolute alcohol equivalent to 3.2 gallons of proof spirit per ton of coal. It has been proved that the calorific effect, reduced by the removal of ethylene from coal-gas, can be restored by the other constituents of coal gas, simply by increased pressure.

Coal Chart

The following chart attempts to portray graphically some of the important by-products of coal and tar.


THE BY-PRODUCTS OF COAL
TAR
COKE
GAS
GAS BY-PRODUCTS
ROAD SURFACES
ANTHRACENE
DYES
PHENOL
PLASTICS
DRUGS
ANTISEPTICS
INSECTICIDES
NAPHTHALENE
SYNTHETIC PORCELAIN
PITCH
WATER PROOFING
RUBBER PROCESSING
IRON AND STEEL
CARBIDE
DOMESTIC AND INDUSTRIAL USES
AMMONIA
BENZENE
TOLUENE
SULPHUR
FERTILISERS
MOTOR SPIRIT
BACTERIA KILLERS
BATTERY ACID
LOCAL ANÆSTHETICS
EXPLOSIVES
BLACK AND BROWN DYES

CHAPTER V

INDIAN COAL

Occurrence

The coal-fields of India belong to two geological periods—the Gondwana System (which corresponds to the upper carboniferous and later deposits) and the Cretaceous or Tertiary beds. The former yield over 97 per cent of the coal mined in India and occurs mostly in Bengal, Bihar and Orissa in a line running due East to West. The latter occurs at Makum in Assam and in the Mianwali district of the Punjab. Of the Gondwana coal, the two principal coal-fields are the Raniganj and the Jharria which between them yield about 72 per cent of the total produced annually. These fields are situated in the Damodar Valley which contains almost all the workable coal-seams of Peninsular India. Except for the Manbhum section, the Raniganj coal lies chiefly in the Burdwan district of Bengal where the first working dates from 1820 while the Jharria coal which lies in the adjoining province of Bihar was first mined in 1893. The other important coal-fields are Bokara, Ramgarh, Karanpura, Giridih (or Kharabhari) and Daltonganj in Bihar and Orissa which are all fed by the East India Railway, the Pench and Wardha Valleys of Central Provinces and the Singareni coalfields of the Hyderabad State. There are a number of smaller mines which have been worked at one time or another. There is evidence of coal occurring in Kathiawar, near Wadhwan and Shaila.

Geology

The Raniganj, Jharria and neighbouring coal-fields must have all at one time formed part of the great continent of Gondwanaland which extended over a considerable portion of the Southern Hemisphere. They are all sedimentary deposits except for two phases of igneous or vol-

canic activity resulting in the intrusion of numerous mica-peridotite and doleritic dykes and sills which are found to intersect the deposits of coal. There are here and there recent and sub-recent alluvial and lateritic deposits on the surface and there is an unconformity between the lower and the upper Gondwanas. The former too rest unconformably on archaic rocks and are divided into three series the middle of which, the Damudas, contains the coal measures. The stratigraphy can be tabulated as follows:—

			Maximum depth
Recent and Subrecent	..	Alluvial & lateritic deposits.	100 ft.
Upper Gondwana	..	Supra-Panchets (Sandstones & Quartzose conglomerates).	1000 ft.
	Unconformity		
Lower Gondwana	Panchet Series (Sandstones, thick red clays and shales).		2000 ft.
	Damudas	Raniganj Measures (Sandstones with shales and coal-seams).	3400 ft.
		Ironstone shales or Barren measures (Shales and clay ironstones) but no coal.	1200 ft.
		Barakar measures (Conglomerates, sandstones shales and coal-seams).	2100 ft.
	Talchir Series (Sandstones, shales and boulder-beds).		900 ft.
	Unconformity.		
Archaeans.			

The photograph on the next page of a section of the Raniganj measures shows a coal seam overlaid by sandstone and laterite.

Formation

From the evidence of the boulder beds in the lowest Talchir Series, it has been suggested that before these deposits were formed there was a period of glaciation and that when the mantle of ice disappeared from over Gondwanaland, a country-side devoid of drainage lines was laid bare over which marshes and lakes formed rapidly, floods were frequent and sedimentation more marked. It has also

been suggested that the several Gondwana Coal-fields in this area which, though scattered today, were once more or less connected and that gneissic islands and hills had stood out of the marshy plains, the subsequent disconnection being due to post-Gondwana faulting and erosion. There is no evidence of the existence of marine or estuarine conditions at any period during the deposition of the Damuda series: the strata are all of fresh-water origin laid down in large open flood-plains, inland lakes or swamps,

the inorganic material being derived locally from the metamorphic land-masses which adjoined these areas of deposition and which, in part, afforded a site for the growth and accumulation of the vegetation from which the coal seams appear to have originated.

Drift Theory

There is no evidence to show that the Gondwana Coalfields have been formed in situ: on the contrary there is strong evidence in favour of the drift theory. There is in the majority of cases no basal underclay representing an ancient subsoil for vegetation: nor are there any roots or rhizophores within the floors of the seams. Evidence has not been observed of the existence of upright trunks or stems and, on the contrary, woody stems of considerable size have been found embedded in a position parallel to the bedding in the form of silicified trunks or ferruginised ironstone inclusions with an outer thin layer of bright coal. Finally, the seams of the Barakar Series often split up into several thin seams separated by wedge-like intercalations of shale and sandstone which are said to represent the finer inorganic material brought down with the mother substance of the coal and re-sorted by the action of currents. It is therefore suggested that with the filling up of the inland gulf which occupied the length of the Damodar Valley during Talchir times the site of the coal-fields was converted into large alluvial flood-plains, and that during the Damuda period these areas were subjected to a general subsidence of an oscillatory character, so that at certain intervals they were exclusively inundated to form wide lacustrine tracts resulting in the deposition of the coal-seams and associated shale and sandstone deposits of the Barren and Raniganj measures. Dr. Fox thinks that the period of time during which the whole of the Damuda sediments were laid down was probably not less than 30 million years and that the time that has elapsed since the deposition of the lowest Barakar coal-seams could be estimated at 240 million years.

Classification

All the Gondwana coal can be divided into two fairly well-marked groups corresponding with the two geological masures, the Barakar and the Raniganj Series. The Barakar coals have a low moisture percentage (under 3.5 per cent), a low percentage of volatiles ranging from 21 to 30 per cent and a high proportion of fixed carbon ranging from 52 to 64 per cent and are excellent steam-coals with a tendency to form a hard metallurgical coke. The coals of the Raniganj series have on the other hand a high moisture percentage between 3 to 10 per cent (except in the Dishergarh seam) and a high percentage of volatiles, between 29 to 38 per cent; these coals with only two exceptions (Dishergarh and Sanctoria seams) fail to coke at all or produce a soft porous coke: they are excellent gas-coals and free-burning steam coals. The coal from the Central Provinces too has a high moisture volatile and ash percentage and a low calorific value. These characteristics of the two different coals have been apparently taken note of by the Indian Coal Grading Board appointed under the Act of the same name in 1926 for the purpose of granting certificates for graded coal intended for export. Their classification into the various grades is as follows:—

	Low Volatile Coal (Barakara and Karahabaree Series)	High Volatile Coal. (Raniganj Series).
Selected	Upto but not exceeding 13% ash and over 7000 calories.	Upto but not exceeding 11% ash; over 6800 calories, under 6% moisture.
Grade I	Upto but not exceeding 15% ash and over 6500 calories.	Upto but not exceeding 13% ash; over 6,300 calories; under 9% misture
Grade II	Upto but not exceeding 18% ash and over 6000 calories.	Upto but not exceeding 16% ash; over 6000 calories; under 10% misture.
Grade III	Coals inferior to above	Coals inferior to above.

In order to ensure that only good sized steam coal is exported from India, the Grading Board only accepts coal which will pass over a screen of two inch mesh at the collieries. This is known as "Steam coal" and forms the first of the three customary sizes in which Indian coal is marketed. The next variety is Rubble Coal which will fall through a 2 inch screen but pass over a ¾ inch screen: then

comes 'Slack coal' which falls through a $\frac{3}{4}$ inch screen. Smaller than slack coal would be 'Dust coal' which is specified upto $\frac{1}{2}$ inch only.

Production

The Jharria coal-field situated about 170 miles west of Calcutta covers an area of 280 square miles and is the most productive of all the coal-fields of India. It had upto 1928 yielded some 450 million tons representing a little under 50 per cent of the total coal produced in India during that period. The Raniganj coal-field about 130 miles west of Calcutta, though covering a wider area of about 500 square miles and being a much older one, produced about 180 million tons upto 1929. The former has 18 seams, the lower nine being of poor quality, and the latter has 20 seams. Between them they produce about 72 per cent of the total Indian output. In the Pench Valley though several seams occur, only four are of workable thickness but of these only the top seam varying from 4 to 8 feet in thickness is worked at present. In the Wardha Valley only one seam contains coal of commercial value varying in thickness from 50 to 80 feet. The output from these Central Indian collieries which was a bare thousand tons in 1905 has increased steadily to about two million tons. The total Indian output thus reached the record figure of 28,342,906 tons in 1938 having exceeded the output of the year previous by 3-1/3 million tons. In 1909, the production was about 12 million tons which rose in a decade by another 10 millions and which continued to remain at about 23 million tons in the early thirtees. Of this about 2 million tons can be reckoned as produced in Native States. These States, apart from Hyderabad which produces more than 50 per cent of the native state production, are in order of importance Rewah, Talcher, Korea, Raigarh, Bikaner, Kalat and Khasi and Jhantia Hills. The following table gives a provincial distribution for 1938 together with total value and value per ton:—

Province	Production Tons.	Value Rs.	Value per ton Rs. As. Ps.
Assam	278,328	24,92,710	8 15 1
Baluchistan	21,882	1,43,910	6 9 3
Bengal	7,745,372	3,10,96,838	4 0 3
Bihar	15,364,079	5,37,10.376	3 7 3
Central India	336,593	13,71,920	4 1 8
Central Provinces	1,658,626	61,18,233	3 11 0
Eastern States Agency	1,463,693	48,79,469	3 5 4
Hyderabad	1,211,163	52,72,033	4 5 8
Orissa	44,425	1,44,002	3 3 10
Punjab	184,028	10,20,856	5 8 9
Rajputana	34,717	1,70,485	4 14 7
Total	28,342,906	10,64,23,835	3 12 1

Output

The average price showed above, viz. Rs. 3-12-1 works out at about 5s. 8d. which compares poorly with an average of 13s. 2d. obtained at the pits' mouth in the United Kingdom, or of 9s. 1d. obtained in America. Even Japan's valuation is about 8 shillings. Our low price has been ascribed to easy accessibility and cheapness of labour. The average output per person employed in India varies between 124 to 130 tons which is practicaly half the average output in the United Kingdom and only one fifth of that of the United States. Even then, our average output is now considerably higher than in former years due to an increased use of mechanical coal-cutters and loaders, picking belts and other modern devices. The number of collieries using electric power is now 120 of which 36 use machines for undercutting.

Mining Methods

The method of working underground is mostly the 'Pillar and Stall' system: originally the pillars were small from 12 to 18 feet square with galleries almost as wide; but now the size is increased, the pillars being 80 to 100 feet wide and the galleries 15 feet with barriers of coal at suitable intervals. The long-wall system is adopted in the Naroamuda Colliery and to some extent in other places. The Pillar and Stall method also prevails in the Pench Valley where the section worked seldom exceeds 8 feet in thickness and only one seam is exploited. In the Wardha

Valley where the sections are thicker and often more than one seam or section is worked, the system is modified to one of panels by which the mine is divided into small areas, each area being surrounded by a barrier of coal through which only a limited number of roadways is driven, so that a fire occurring within a panel can be quickly sealed off from the rest of the mine.

Labour

The average number of persons employed in the Indian Collieries is a little under two lakhs, one-fourth of which works underground. Of the labourers working underground at least ten per cent are females. The classes from which colliery labour is recruited being largely agricultural, supply is adversely affected by a favourable monsoon as the cultivator will only take to mining when his crop fails or savings are exhausted. There are still one or two pits where coal is raised in the primitive way, through buckets of coal being hauled to the surface by women by means of pulleys fixed at the top of shallow shafts and being then emptied into adjoining tubs for transportation to the depot. The methods at most collieries are, however, uptodate and labour is well-looked after with modern comforts of creches, clinics, schools etc. The death rate due to accidents is, as we have seen, quite low being 1.2 per thousand for an average period of fifteen years. The subsidiary industries at the Bengal collieries viz. Brick and Pottery Works, Fireclay and Silica Works; Iron and Engineering Works, Wagon Manufactory, Paper Mills, etc. employ a large number of industrial labour.

Exports

While we have been importing annually decreasing quantities of coal from foreign sources (chiefly England and Natal), our exports of Indian coal have been mounting, especially due to various factors connected with the war. The chief foreign consumers of Indian coal are Ceylon, Burmah and the far Eastern Countries and latterly China. The shipments of Indian coal during 1939-40 attained the

unusually large figure of 2 millon tons as compared wtih 1 3 and 1 0 million tons in the two preceding years. The coal shipped for export is usually of good quality so that there is an excess of production of other grades over the demand for internal consumption. This consumption is reckoned at about 22 million tons.

Uses

The purposes for which Indian coals are utilised include steam raising and the manufacture of coal gas, metallurgical coke, soft coke and powdered fuel. Barakar and Jharria coals are short-flame coals and are therefore better suited for locomotive boilers than for boilers with a forced draught for which the Raniganj coals are said to be the best. The latter are also good for manufacturing coal-gas but not effective for metallurgical coke. We shall refer to soft coke presently. As regards powdered fuel, the stock of certain Raniganj coals is used by the Indian Copper Corporation for copper refining on account of their high volatile content giving easy ignition, refractory ash preventing clinkering and low sulphur content. The greatest consumers then of coal in India are the Indian Railways which require over 7 million tons annually, or about 32 per cent. About 2½ million tons of this is the output of collieries owned by the Railway Companies themselves. The next best consumers are the Iron, Steel and Brass foundries which take in about 25 per cent and which too control certain collieries. The consumption at the collieries and in the Cotton Mills is over a million tons apiece and a like quantity is required for bunkering (which quantity increased considerably when the Mediterranean route was closed and steamers had to perform longer voyages). The other notable consumers are inland Steamers and Port Trusts, Brick and Tile factories, Potteries and Cement Works, Paper and Jute Mills, Tea Gardens, etc. The consumption of coal per head of the population is reckoned at .06 ton: this consumption is naturally low as mined coal is not used for domestic purposes in tropical India. While the

Bengal collieries are all 'proprietary,'* those in the Central Provinces have to pay a royalty of 5 per cent of the pit-mouth value or two annas per ton whichever is greater (and half that amount for coal dust) as all mineral rights are vested in the Central Government.

Soft Coke

There is an extensive manufacture of soft coke (**poora-koela**) within the Raniganj and Jharria coal-fields by small proprietors working inferior seams which are regarded as unfit for steam raising and other purposes. The lump coal is stocked in large heaps varying upto about 20 tons and is ignited from a hole at the top of the heap. The heaps are then covered with a layer of slack and dust coal and combustion is allowed to proceed gradually for about 3 to 4 days until the whole of the coal is affected in a greater or less degree. The result is a soft coke or semi-coke resembling the product obtained by low temperature carbonisation, representing 60 to 70 per cent of the total weight. It is said to be ideal as a domestic fuel on account of easier cooking, easy ignition, absence of smoke, regulation of heat, easy storage and comparative cheapness. Indeed, the Indian Soft Coke Cess Committee carries on an intensive propaganda for the popularisation of soft coke in Indian kitchens. The Committee is financed by a cess of 2 annas per maund levied as a surcharge on railway freight on all coke despatched by rail from the collieries. Soft coke is said to be very popular in Bengal.

Jhama

We have seen that there are intersections among the coal-seams of igneous dykes and sills due to volcanic activity. These in conjunction with superheated steam have altered the coals in their immediate vicinity to a dense hard prismatic structure: the coals being coked by the highly heated molten intrusions. Such coked coal is known as

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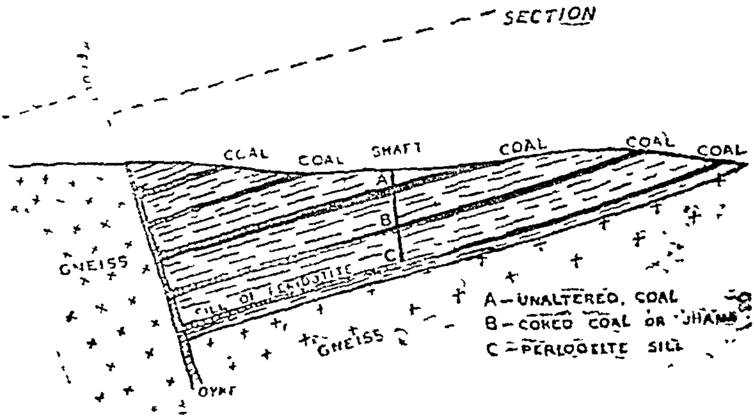
* This has led to curious developments in that the Railway Companies claim the coal lying under their railways and the Govt. of Bengal that lying under the Grand Trunk Road and both will not permit such coal to be tapped, thus locking up some 33 million tons.

Jhama. The following figure shows the relationship between sills and dykes and the formation of Jhama. The shaft A B C penetrates coal at A. Jhama at B and peridotite at C.



This natural coke is dull, dense and hard: it is occasionally vesicular in structure, dark or silvery-grey in colour, a non-conductor of heat and electricity and does not possess the reactivity for carbon dioxide of metallurgical coke. It has been estimated that there are at least 400 million tons of Jhama within workable depths half of which may be entirely worthless and the balance, though suitable as the finest material for manufacturing producer gas in the absence of true anthracite in India, is not yet used, probably on account of high mining costs.

Spontaneous Combustion

The above coking into Jhama should not be confused with the surface burning of outcrops in comparatively recent times, though probably long before the evolution of man. The combustion of surface outcrops appears to have continued to a maximum depth of 30 to 40 feet and then died out, evidently due to lack of air or to the presence of water. While the coal itself has burnt itself to ashes, the prevailing heat has been sufficient to fuse the overlying strata of shales and sandstones. As the coal burnt completely.

this debris must have caved in. The combustion appears to have been due to the oxidation of coal on exposure to the air: if the heat generated by freshly mined coal is not dissipated, the temperature would rise slowly until the coal becomes thoroughly heated to burst into flames The clinkers, fused masses and other debris of the burnt outcrops apart from being used for stowing, road-making or filling the hollows, serve as useful guides in tracing the outcrops of concealed seams. Under the Coal Mines Safety (Stowing) Act of 1939, an excise duty of 2 annas per ton on coal and soft coke and 7 annas per ton on hard coke is levied for the purpose of creating a fund for assistance towards stowing. There is a Board for the purpose of financing stowing operations as well of taking steps to reduce the dangers to a coal-field from the very large fire areas which are said to be active. The danger of spontaneous combustion is very great in the Wardha Valley where the coal has a very high moisture content, disintegrates rapidly and cannot be stocked for long periods: in the neighbouring Pench Valley the coal is hard and tough.

Composition

The bulk of Indian Coal is bituminous and laminated with alternating dull and bright layers. Much of it as we have seen does not coke freely though Jharria, Giridih and some Raniganj coals are fairly good for coking. They have however an ash percentage of 10 to 15; this percentage is much higher for Central India and Hyderabad. The average carbon content for Raniganj is below 55 per cent but rises to 65 per cent or more for Jharria and Giridih. In the Central Provinces it is under 47 per cent. The moisture content varies in the upper and lower seams and is as high as 14 per cent for Central India. Sulphur and phosphorus occur in variable quantities in the different seams and may be regarded as 0.65 and 0.13 per cent respectively. The average hydrogen percentage for Bengal Coal is 4.10 and of oxygen 8.03. The average calorific value may be reckoned at 10 to 11,000 British thermal units as against 14,000 for English raw coal.

Bye-Products

The best Bengal coal which has a carbon percentage of 71.47 yields the following bye-products per ton in Kopper's recovery ovens:

Coke 75 per cent ;
Gas 9000 to 10,000 cu. feet ;
Coal Tar 4.35 gallons ;
Crude Benzol 2 gallons;
Ammonium Sulphat 25 lbs.

Except coke, gas and tar, the other by-products are not yet recovered in India. Even at Jamshedpur. the majority of ovens being old type are not suited for by-product recovery. A portion of the gas evolved is used in heating the retorts: the remainder is available for power and other uses. Coke is produced at the coal-fields as we have seen from low grade coal, and at Jamshedpur for the purposes of smelting. Only small quantities of coke are exported.

Reserves

Very few collieries in India are working today beyond a depth of 500 feet although there are indications that seams might be worked upto a depth of 4,000 feet. The estimates of coal reserves are therefore worked for a depth of 2,000 feet. Mr. Simpson estimates a total of 1,800 million tons of superior quality Coal as the reserve of India and states that, being only about seven times the output of Great Britain, it would hardly supply the demand of the United States for more than three or four years. Estimating that this reserve will be exhausted in about 45 years, he considers it a serious prospect, seeing that not more than 2/3rds of the reserve is suitable for the production of metallurgical coke and that there are large resources of high grade iron ore in the country which requires a coke of a better quality for smelting. He therefore recommends the prohibition of Jharria Coal for any other use than coke-making. Dr. Fox. who has studied the Jharria coal-field exhaustively and has written geological memoirs on the subject, thinks that the annual despatches from this field being computed at 8 to 10 million tons, the reserves to a depth of 1,000 feet must be exhausted within 40 to 50 years and it

CHAPTER VI

MISCELLANEOUS

Coal Laminae

We have referred to the fact that coal, and especially bituminous coal, has a laminated appearance of dull and bright bands. These bands are due to four distinctive and visibly differing portions which are known as fusain, durain, clarain and vitrain. **Fusain** is equivalent to what we have described as mineral charcoal and occurs as patches or wedges of powdery, readily detachable, somewhat fibrous silky strands, flattened parallel to the bedding plane. **Durain** is dull, hard coal and occurs as bands of variable thickness, usually lenticular in shape, having a close, firm and somewhat granular texture. **Clarain** and **Vitrain** form bright coal and occur as narrow bands, often lenticular in shape, exhibiting a hard, glassy appearance. They exhibit marked caking properties unlike durain and their fracture is conchoidal.

Ventilation in Coal Mines

An average man is said to require about 500 cubic inches of air per minute when at rest and 1,500 cubic inches when walking. As working in a coal-mine involves more violent exercise than walking, the quantity required by a miner would be, say 1,728 cub. inches or one cubic foot. A horse requires six times that quantity and an ordinary safety lamp about half. Now, air in mines is vitiated not merely by breathing of men and horses or by burning of lamps, but also through the use of explosives, the various gases given off from the strata, watery vapour, coal dust and underground or gob-fires. It is impossible to calculate the quantity of air required to offset this vitiation and thereby to keep a mine in a safe condition but it has been

found in practice that 100 cubic feet of air per minute per person in mines free from gases is sufficient for all purposes: this quantity must be increased in fiery mines upto even 500 cubic feet.

The ventilation of a mine consists in the keeping up of a regular supply of pure fresh air to remove and replace the impure air that is being constantly generated. It is therefore necessary to create ventilating currents as a result of a difference in pressure at different points, the density of air in the upcast shaft being reduced by natural or artificial means, so that the heavier air in the downcast shaft tends to move in the direction of the rarefied air through the 'intakes' to the 'returns'. Stoppings or stentons to prevent the air from taking the shortest route to the upcast are built between main airways with bricks or stones while other temporary stoppings may be of wood. Sometimes, doors or even double doors are provided in the intakes and where intake and return currents have to cross each other, an 'air-crossing' bridge is built by which the latter is taken over the former separated by a wooden crossing.

Where there is no 'natural' ventilation, artificial methods are employed either for reducing the density of the air in the upcast shaft or for increasing it in the downcast. This is done variously by furnace, steam jets, exhaust or blowing fans, varying capacity machines, air-pumps, waterfalls, wind cowls, etc. The furnace is usually placed a short distance away from the bottom of the upcast shaft and produces ventilation by rarefying or reducing the density of the return air. The steam jet by which high pressure steam is injected into the upcast is an expensive affair and therefore not much favoured. Exhaust fans are placed at the top of the upcast, a few yards away from the pit opening so as to escape damage in an explosion. The blowing fans now universally employed are of various patterns and makes but must be all so constructed as to convert them from exhaustive to compressive fans so as to reverse the direction of the air-current in the case of an accident or fire. The varying capacity machines which act by pump-

ing the air are rarely applied, being liable to derangement. Waterfalls by which water is scattered down the shaft like rain thereby producing a downward current can only be useful in small mines which have a proper adit for draining the water. The wind cowl can only be used temporarily when surface wind which can be diverted down a shaft is blowing. Whatever be the method employed, the Act requires that "an adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless inflammable and noxious gases to such an extent that all shafts, roads, levels, stables and workings shall be in a fit state for working and passing therein".

Heat-Units

The unit of heat in any system of units is the quantity of heat required to raise the temperature of unit mass of water through 1°. Thus, the calorie is the quantity of heat required to raise the temperature of one gram of water through 1°C; and the British Thermal Unit is the quantity required to raise the temperature of one lb. of water through 1°F. Calories can be converted into British Thermal Units by multiplying by 9 and dividing by 5. Now, coal is composed of carbon, one lb. of which yields 14,500 units of heat, hydrogen one lb. of which yields 62,032 units and sulphur one lb. of which yields 4,032 units. It is also composed of oxygen but this combines with a portion of the hydrogen to form water. The total heat of combustion of average British Coal would therefore be (14,500 x .80 + 62,032 x (.05 — .08/8) + 4,032 x .0125)* = 14,131 British Thermal Units or 7,850 calories. Similarly for Indian Coal, it would be (14,500 x .70 + 62,032 x (.04 — .08/8) + 4.032 x .006) = 12,035 B. T. U. or 6,686 calories, according to composition. Coke containing .86 carbon and no hydrogen or oxygen would yield 12,470 B. T. U. but peat would yield only 9,940 or less.

Charcoal

The word 'Charcoal' represents the residue obtained by

* In this calculation .80, .05 and .0125 represent the percentage fractions of carbon, hydrogen and sulphur, a deduction of .08/8 being made on account of its combination with hydrogen to form water.

partially burning or heating carbonaceous materials: these materials may be either of animal or vegetable origin. We may thus get blood charcoal, bone charcoal, sugar charcoal, wood charcoal etc. We are only concerned with the last named as it is the wood charcoal which is used as a substitute for and generally confused with coal. Indeed even in England, wood charcoal was used in place of coke in ancient days for iron-smelting. In India, it is now used largely as a domestic fuel.

In the primitive way, charcoal is made by stocking cut wood into heaps with a vent in the middle and then setting it alight. The heat developed by the burning of a portion of the wood helps to carbonise the remainder, the heat being regulated by controlling the access of air or by covering the heaps with earth, turf, etc. In the most modern methods, carbonisation takes place in retorts so that certain bye-products like wood-tar, spirit, acetic acid etc. can be recovered. The proportion of charcoal obtained is about one-fourth of the weight of the wood. Since the tarry and volatile matters are driven off during carbonisation, charcoal is a clean fuel; also the calorific value by weight is twice as great as for original timber.

Charcoal of certain light woods, like willow and alder, is used in the manufacture of gunpowder along with nitre and sulphur. Charcoal has the exceptional property of removing colouring matters from solution and is therefore of value in treating beet-sugar juice. Charcoal also absorbs gases—a fact which will be apparent by reweighing given loads in monsoon weather when the charcoal will be found to have gained in weight through the absorption of water vapour. This property was availed of during and after the first World War in the manufacture of gas-masks when 'activated' charcoal (i.e. charcoal kept at a red heat for some time with limited access of air so as to increase its absorbing powers) formed a component of respirators supplied to the troops as a precaution against gas-warfare. Here, coconut shell-charcoal was found to be the most effective.

The fact that wood charcoal which is nothing else but charred wood is exceptionally resistant to decay is made use of in the building of floating houses in Venice where the wooden piles on which these houses stand have all been charred in order to secure their better preservation.

Any kind of timber can be used for carbonisation into charcoal but the kind much preferred in India is Babul (**Acacia Arabica**) as it burns better and gives proportionally more intense heat.

World Production

In view of the statement that the most progressive countries today are those possessing ample resources of coal which are being extensively exploited, the following statistics of annual production of coal including lignite, in million tons arranged in order of importance, will be of interest:

1.	United States	....	487.00
2	Germany	....	360.70
3.	United Kingdom	....	240.00
4.	U.S.S.R.	....	121.90
5.	France	....	45.10
6.	Japan	....	40.00
7.	Poland	....	35.35
8.	Czecho Slovakia	....	34.92
9.	Belgium	....	30.40
10.	India	....	23.16
11.	South Africa	....	15.24
12.	Australia	....	15.00
13.	China	....	14.00
14.	Canada	....	13.59
15.	Netherlands	....	13.50
16.	Manchukuo	....	12.00
17.	Hungary	....	8.00
18.	Spain	....	7.00
19.	Yugoslavia	....	4.50
20.	Austria	....	3.50
21.	Bulgaria	....	2.60
22.	Turkey	....	2.50

23.	French Indo-China	2.25
24.	New Zealand	2.20
25.	Chile	1.90
26.	Rumania	1.90
27.	Formosa	1.60
28.	Italy	1 50
29.	Mexico	1.40
30.	Spitzbergen	0.77
31.	Southern Rhodesia	0.72
32.	Sweden	0.60
33.	Malaya	0.50
34.	Nigeria	0.29
35.	Irish Free State	0.12

World Distribution

The superficial extent of the coal areas of the world are estimated at 605,000 square miles or in the ratio of 1 to 110 of the land surface of the globe, about one-third belonging to formations later than carboniferous. Coal is found in all latitudes but is of better quality in the Old World than in the New, and in the Northern Hemisphere than in the Southern.

The United States is the largest producer of anthracite and bituminous coal in the world, though its reserves of anthracite which are in Northern Pennsylvania are relatively small. Coal is mined in 39 States, bituminous coal being worked east of the Mississippi and lignites in the Northern Great Plains and Gulf provinces. There is comparatively little coal on the Pacific Coast. The average annual production is between 400 and 450 million tons of which barely 3 per cent is exported, mostly to Canada—the coal-fields being all situated far away from the shipping centres.

Germany produces about 350 million tons annually half of which is lignite. In fact, it is the largest producer of lignite in the world and its coal reserves are the largest in Europe. The Rhine coal-fields in the heart of industrial Germany produce bituminous coal while the output of Upper Silesia, the second largest field, is used both intern-

ally and for export. Lignite is produced in Central Prussia: a large portion of it is dried or converted into briquettes before use. Germany used to export about 20 to 25 million tons annually to France and other continental countries.

The United Kingdom produces about 240 million tons annually and exports about 40 million tons to the continent and South America, being thus the largest exporter in the world. The coal-fields are all distributed in close proximity to the shipping ports. The coal produced in the United Kingdom, both anthracite and bituminous, is said to be of the highest quality in the world. Lignite is only worked to a limited extent in Devonshire. Anthracite is found largely in Wales. Many authorities have stated that "the length of time during which England will continue to hold her prominent position as an industrial nation is limited by the time during which her coal will last".

Russia has shown a phenomenal increase of production in recent years. In the beginning of this century it was producing very little. In 1926 its production reached 24 million tons and in 1937 it was five times as much. Russia now ranks among the world's largest producers. Its best coal-field is in the Donetz basin of South-east Ukraine providing about 75 per cent of that country's output. This field has an easy outlet to the Black Sea and yields both anthracite and bituminous varieties. There is an extensive lignite deposit, south and west of Moscow, supplying the industrial needs of that city: and there are also coal-fields in the Ural Mountains. One of the largest coal-deposits of the world is in Kuznetsk basin in Central Siberia: it still awaits large scale exploitation. Many of the Russian coal-bearing strata do not belong to the upper or true coal measures but to either the carboniferous limestone or to the lower coal measures which have provided the workable coal seams of Scotland.

France, though a large producer, consumes much more and is therefore a large importer. Its most important coal-field is in the Pas de Calais which was occupied by the

Germans in the first War and whose mines were destroyed but had to be re-equipped as a part of the reparation payments.

Among the other countries, Japan is a large consumer and though its own coal stocks are poor, has large deposits in Manchuria which, though controlled by the South Manchurian railway, were under Japanese influence. The main Polish coal-fields are near Silesia, being ceded to Poland after the first war: they proved a serious competitor with the older coal-exporting countries bordering on the Baltic. China has at least one coal-field in every Province but none has been properly exploited: nor are the lignite deposits of Korea. The most important coal-field of Australia is round New Castle in New South Wales where the seams range from 3 to 5 feet in thickness. A large lignite deposit is being worked in Victoria. Tasmania contains true coal and New Zealand is rich in lignites. The African coal deposits along the banks of the Zambesi were discovered by Dr. Livingstone who also collected gold dust in the same field. The Transvaal fields are in close proximity to the Witwatersrand goldfield. There are also extensive fields in Natal and Rhodesia, the latter having contributed to the development of the copper fields of Northern Rhodesia. In South America, coal seams occur in the different provinces of Brazil, Chile and Peru. In fact, supplies of coal are available over a wide area of the earth's surface, there being very few countries completely devoid of them.

World Reserves

The estimated coal reserves known to the world today are estimated by the International Geological Congress of Toronto to be of the following order:

Anthracite	500,000 million tons
Bituminous	4.000,000 million tons
Lignite	8,000,000 million tons

Of the reserves of anthracite, the bulk or four-fifths, appears to be in Asia, the European countries rapidly exhausting their supplies: while the American Continent has

by far the best stocks of bituminous and sub-bituminous coals. It has been estimated that at the present rate of output and consumption, the North American resources, especially, those of the United States will outlast all other countries and will probably suffice for over 2,000 years. Great Britain's supplies on the other hand will not last beyond 600 years and, if depths only upto 4,000 feet are worked, beyond 450 years. Germany had before the present war coal for about a thousand years apart from lignite while Belgium's supplies would have lasted for 500 years. Switzerland has supplies only for a few years. We have already considered India's position in this respect in the last chapter.

EPILOGUE

The object of publishing this monograph is to give general information about coal which would be useful to an average Indian reader. There are a number of books on the subject, but these are written from foreign standards and do not deal with Indian Coal in a comprehensive manner. There are similarly Memoirs and Records of the Geological Survey of India dealing specifically with the various Indian coal-fields, but these are either too detailed or too technical. The need is, therefore, felt of a small manual which may dscribe the origin, composition, mining and derivatives of coal in general and at the same time do sufficient justice to the mineral wealth with which Nature has endowed us. There is in certain districts a tendency to confuse natural coal with artificial charcoal: this is probably due to the non-availability and non-user of coal for domestic purposes and to the consequent unfamiliarity with and ignorance about a substance with which every English boy or girl is intimately acquainted from infancy. It is the object of this book to dispel this unfamiliarity and ignorance, to make coal known and appreciated beyond its use as a fuel in railway locomotives, to impress upon the reader that not merely the energy stored for millenniums in this black rock is being harnessed and re-utilised for generating power but that the substance itself is a veritable store-house of valuable bye-products undreamt of in the philosophy of our ancestors, and above all, to make him realise that if industrial supremacy of a country is regarded as dependant upon its possession of black diamonds, we, in unindustrialised India, cannot blame Nature for her frugality towards us in this respect.

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